

# 1 Executive Summary

## 1.1 Scope

### 1.1.1 USEPA Requirements- Code of Federal Regulations 146.4

An aquifer may be exempted as a potential USDW by the Division if:

*“a) It does not currently serve as a source of drinking water; and  
b) It cannot now and will not serve as a source of drinking water because:*

*(#1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.*

*(#2) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical;*

*(#3) It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or*

*(#4) It is located over a Class III well mining area subject to subsidence or catastrophic collapse; or*

*c) The total dissolved solids content of the ground water is more than 3,000 mg/l and less than 10,000 TDS mg/l and it is not reasonably expected to supply a public water system.”*

### 1.1.2 In response to Code of Federal Regulations 146.4:

- Water well information is provided to demonstrate that the Monterey Formation and Sisquoc Formation below the Upper Confining Layer in the Cat Canyon Oil Field for which the aquifer exemption expansion is recommended *“does not currently serve as a source of drinking water.”*
- Hydrocarbon production, geologic, hydrogeologic, water composition and treatability information is included to demonstrate that the Monterey Formation and the Sisquoc Formation below the Upper Confining Layer for which an aquifer exemption expansion is recommended *“cannot now and will not serve as a source of drinking water”*.
- Water composition and treatability information is included to demonstrate that the Monterey Formation and the Sisquoc Formation below the Upper Confining Layer for which an aquifer exemption expansion is recommended *“is not reasonably expected to supply a public water system”*.

The Monterey Formation and the Sisquoc Formation below the Upper Confining Layer produce oil within the Cat Canyon Oil Field. The formations contain water with average Total Dissolved Solids (TDS) ranging from 7,668 mg/L to 22,007 mg/L as shown in **Table 1.1-1, Cat Canyon Oil Monterey Formation / Sisquoc Sand Water Composition**.

Table 1.1-1: Cat Canyon Oil Monterey Formation / Sisquoc Formation below the Upper Confining Layer Water Composition(mg/L)											
Area	Formation		TDS	B	Na	CL	SO4	HCO3	Ca	K	Mg
Sisquoc	All Sisquoc Data	Mean	9990	26	1151	3266	116	4680	110	47	214
		Std. Dev.	8028	9	721	2812	218	5196	51	59	177
		Count	38	28	28	36	27	29	9	27	27
	Sisquoc: Post Steaming Production	Mean	5862	26	961	1924	75	2209	104	41	247
		Std. Dev.	2600	9	426	1200	46	1572	50	60	179
		Count	27	25	22	27	22	22	8	22	21
	Sisquoc: Native Formation	Mean	19862	34	2311	7436	295	11004	113	71	91
		Std. Dev.	7558	17	1612	2269	500	6143	67	46	113
		Count	12	4	7	10	5	8	2	6	7
	Monterey	Mean	10417	7	1153	3216	57	4657	82	26	98
		Std. Dev.	6445	5	798	1828	51	2395	73	23	82
		Count	14	14	14	14	14	14	6	14	12
Central	Sisquoc	Mean	10745	28	1641	4001	47	5539	29	36	21
		Std. Dev.	3815	20	801	1420	22	2496	8	24	17
		Count	14	11	11	11	11	11	4	11	8
	Monterey	Mean	12314	19	1188	4033	67	5109	44	41	56
		Std. Dev.	6823	22	454	1958	87	2221	7	68	37
		Count	17	7	16	16	17	17	5	16	15
East	Monterey	Mean	10417	7	1153	3216	57	4657	82	26	98
		Std. Dev.	6445	5	798	1828	51	2395	73	23	82
		Count	14	14	14	14	14	14	6	14	12
	Sisquoc	Mean	7668	12	1263	2740	27	3528	41	16	73
		Std. Dev.	2547	12	768	1019	20	1806	12	11	51
		Count	17	9	14	14	14	14	2	13	13
West	Monterey	Mean	12314	19	1188	4033	67	5109	44	41	56
		Std. Dev.	6823	22	454	1958	87	2221	7	68	37
		Count	17	7	16	16	17	17	5	16	15
	Sisquoc	Mean	22007	42	876	8063	147	12252	15	50	49
		Std. Dev.	5280	29	442	2096	103	3700		28	94
		Count	9	5	8	8	8	8	1	8	5
Gato Ridge	Monterey	Mean	9118	29	1769	3207	29	4003	41	14	62
		Std. Dev.	1151	14	528	367	11	698	11	10	74
		Count	55	40	42	51	52	42	5	40	34
	Sisquoc	Mean	21000								
		Std. Dev.									
		Count	1								
	Sisquoc/ Monterey	Mean	6333								
		Std. Dev.	153								
		Count	3								

Reinjected water in the Cat Canyon Oil Field includes steam injection, water flood and some produced water re-injection. Produced water re-injection is considered a critical production activity necessary for enhanced oil recovery. Produced gas which cannot be used or sold is reinjected with the produced water in some instances where appropriate.

### 1.1.3 California State Requirements- Public Resources Code 3131(a)

An aquifer may be exempted as a potential USDW by the Division if:

- “#1) [It meets] criteria set forth in Section 146.4 of Title 40 of the Code of Federal Regulations.
- #2) The injection of fluids will not affect the quality of water that is, or may reasonably be, used for any beneficial use.
- #3) The injected fluid will remain in the aquifer or portion of the aquifer that would be exempted.”[ed.]

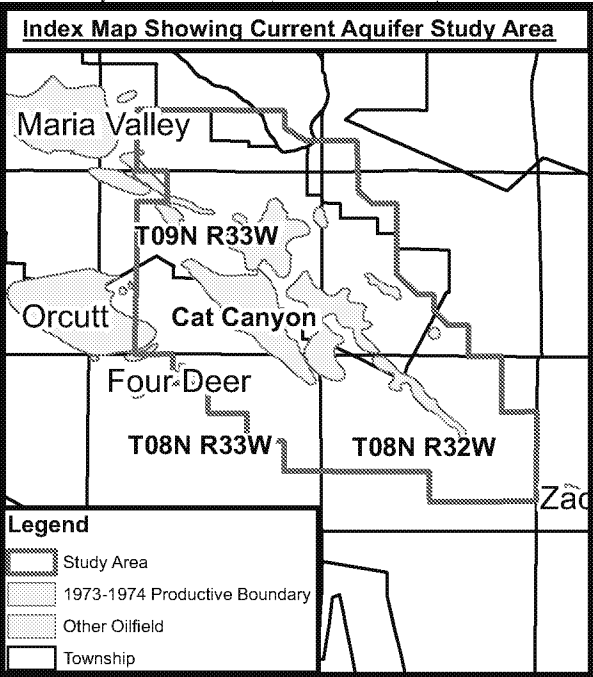
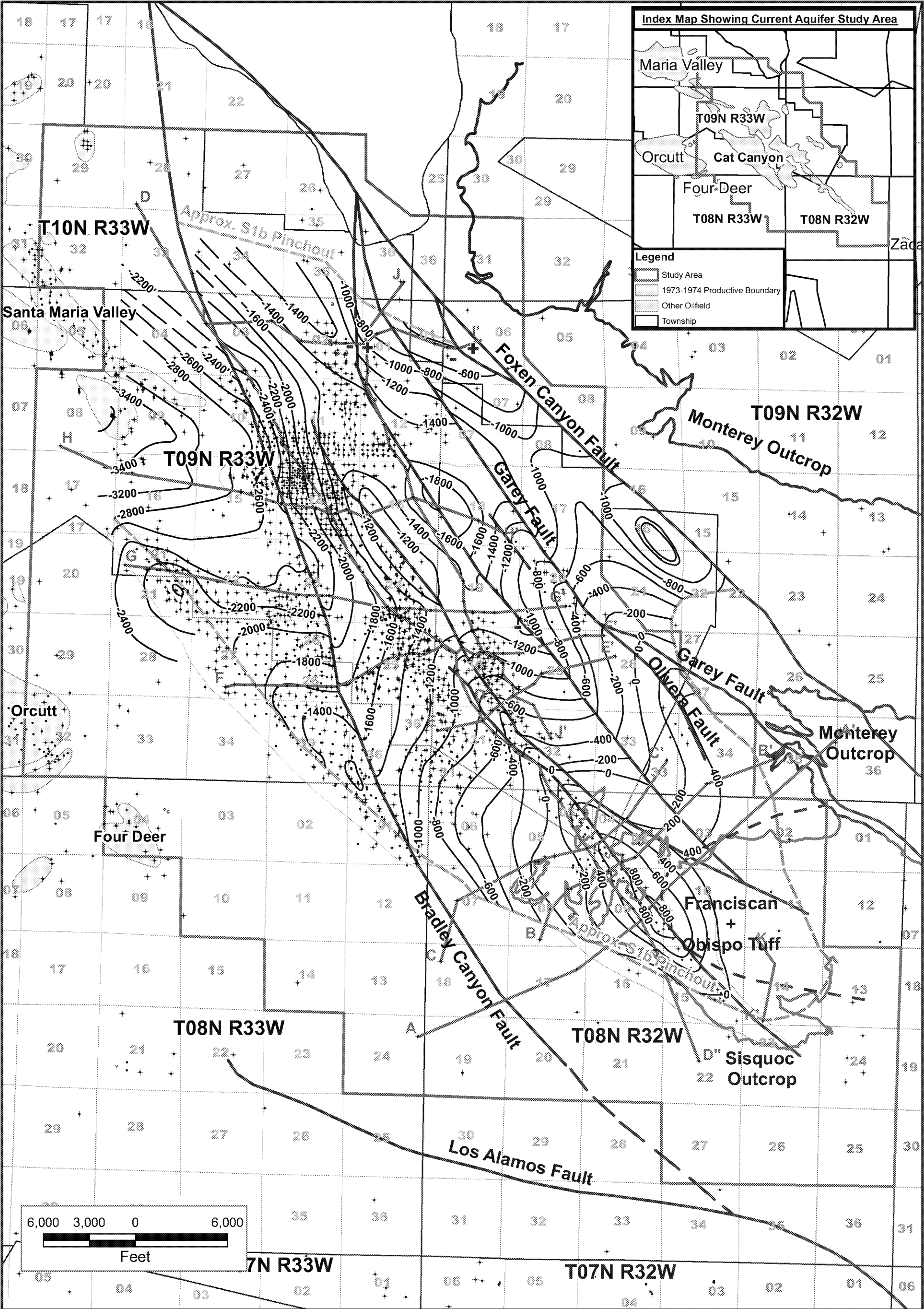
#### 1.1.4 In response to Public Resources Code 3131(a):

- Hydrocarbon production, geologic, hydrogeologic, composition, and treatability information is included to demonstrate conformance with “*Section 146.4 of Title 40 of the Code of Federal Regulations*” for the Monterey Formation and the Sisquoc Formation below the Upper Confining Layer for which an aquifer exemption is recommended.
- Hydrologic and water composition information is included to demonstrate the absence of “*reasonably ... beneficial use*” of the Monterey Formation and the Sisquoc Formation below the Upper Confining Layer for which an aquifer exemption expansion is recommended.
- Geological information is included to demonstrate the geologic containment of the Monterey Formation and the Sisquoc Formation below the Upper Confining Layer of the Cat Canyon Oil Field for which an aquifer exemption is recommended.

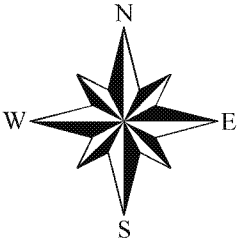
#### 1.2 Summary

The proposed Aquifer Exemption expansion, **Figure 1.2-1, Proposed Aquifer Exemption Boundary for Sisquoc Formation below the Upper Confining Layer** and **Figure 1.2-2, Proposed Aquifer Exemption Boundary for Monterey Formation**, shows the total extent of the proposed exemption boundary. The Monterey Formation and the Sisquoc Formation below the Upper Confining Layer of the Cat Canyon Oil Field are stratigraphically isolated from the groundwater formations in the field by a clay interval above the Sisquoc Formation below the Upper Confining Layer and by clay/shale interval in the top of the Point Sal Formation below the Monterey Formation. In addition the Monterey Formation is isolated from the Sisquoc Formation below the Upper Confining Layer by a clay interval at the base of the Sisquoc Formation.

The proposed aquifer exemption expansion covers an area of approximately 30 square miles. Although the Sisquoc Formation below the Upper Confining Layer and the Monterey Formation have various current existing exemptions in the Cat Canyon Oil Field, the proposed expansion of their areal and vertical extents will provide consistency throughout the field.



- Legend**
- Down
  - Up
  - WellStatus
    - Active
    - Buried
    - Idle
    - New
    - Plugged
    - Volcanics
  - Cross Sections
  - Monterey Outcrop
  - Sisquoc Outcrop
  - Elev. Contour (200f)
  - Approx. Elev. Contour (200f)
  - Faults
  - Approx. S1b Pinchout
  - Study Area
  - Proposed Expanded Sisquoc Aquifer Exemption Boundary
  - Other Oilfield



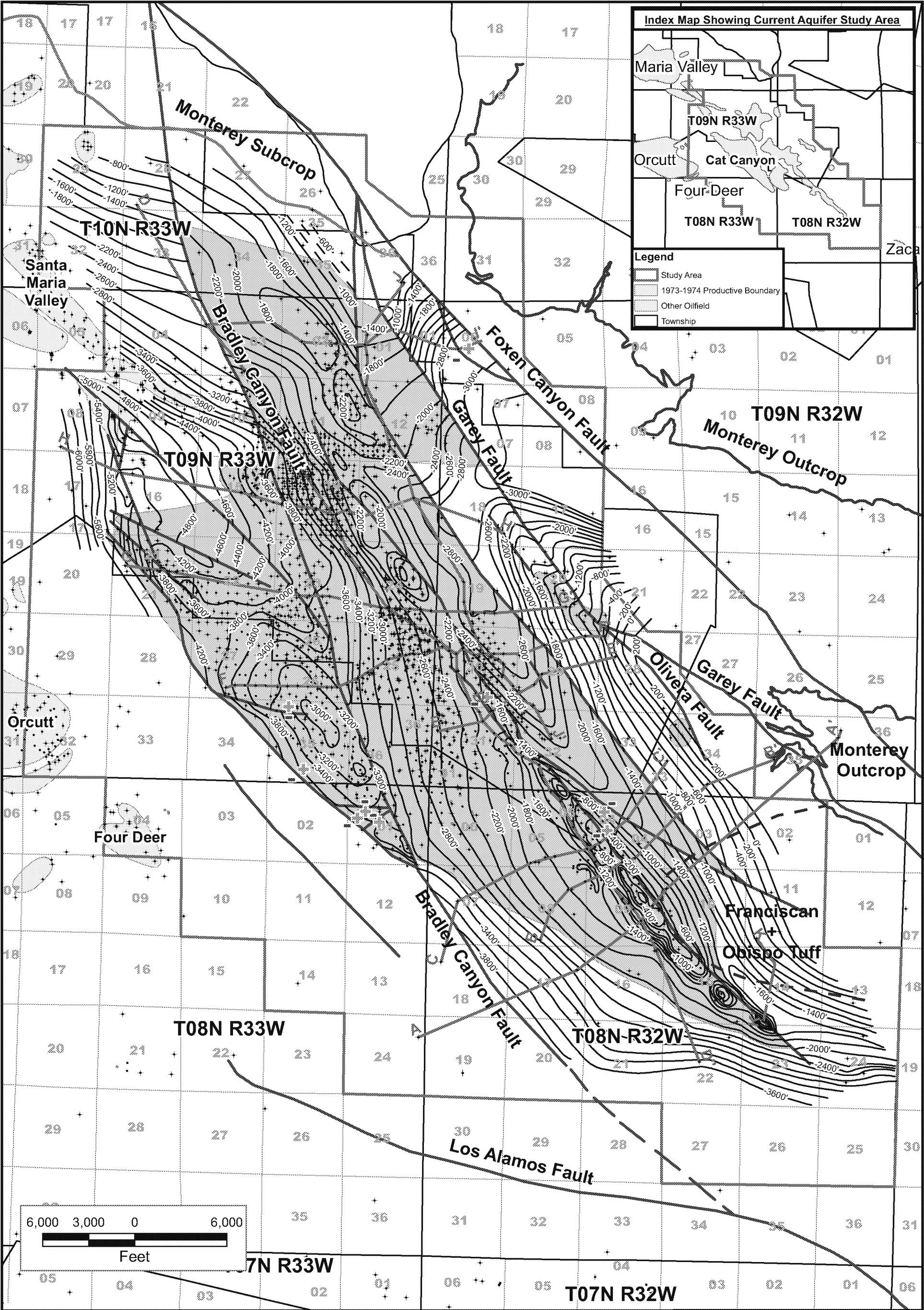
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BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

PROPOSED  
AQUIFER EXEMPTION BOUNDARY  
FOR THE SISQUOC FORMATION  
BELOW THE UPPER CONFINING LAYER

DATE: 11/17

FIGURE: 1.2-1



**Legend**

**Fault Throw**

- Down
- Up

**WellStatus**

- Active
- Buried
- Idle
- New
- Plugged

**Cross Sections**

- Monterey Subcrop
- Volcanics
- Top Monterey Structure
- Monterey Outcrop
- Faults

**Study Area**

- Proposed Expanded Monterey Aquifer Exemption Boundary
- Other Oilfield

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**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

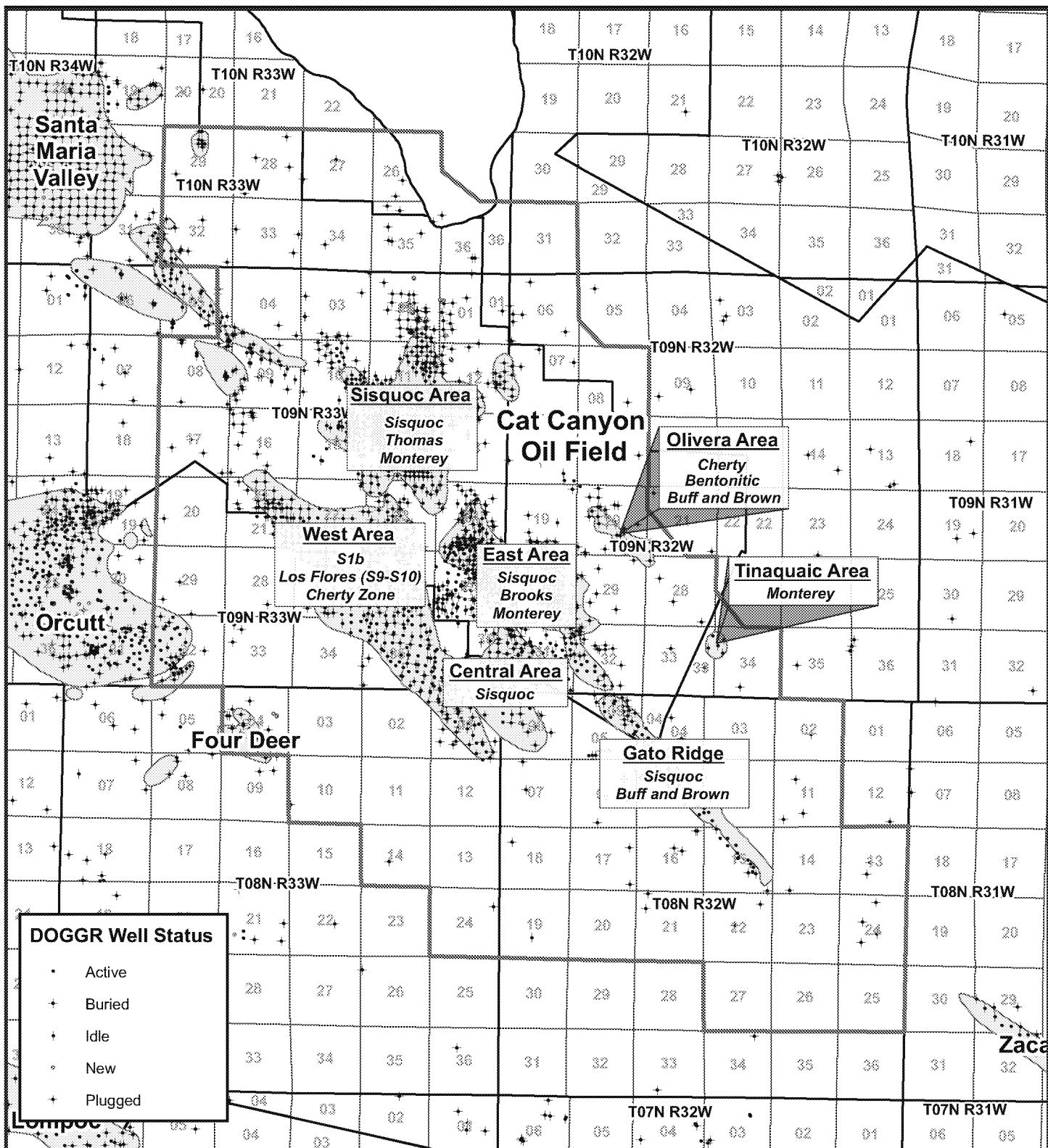
PROPOSED  
AQUIFER EXEMPTION BOUNDARY  
FOR THE MONTEREY FORMATION

DATE: 10/17      FIGURE:1.2-2




The Siquoc Formation below the Upper Confining Layer and Monterey Formation are hydrocarbon bearing and producing with the assistance of steam injection, and water flood for enhanced recovery. Water is also injected into both zones for purposes of disposal. Water reinjection and gas reinjection into the exempt area is currently utilized as part of the current Maximum Efficient Rate (MER). **Figure 1.2-1, Proposed Aquifer Exemption Boundary for Siquoc Formation below the Upper Confining Layer** and **Figure 1.2-2, Proposed Aquifer Exemption Boundary for Monterey Formation**, shows the location of Proposed Aquifer Exemption Expansion Areas in the Cat Canyon Oil Field. Historic exemption status was not consistent with the producing areas at the time of the original delegation by US Environmental Protection Agency (EPA). **Table 1.2-1** shows the historic status and the proposed exemptions by five (5) Areas within Cat Canyon Oil Field (Central, West, East, Siquoc and Gato Ridge). The producing areas are shown on **Figure 1.2-3, Current Aquifer Exemption Boundary**.

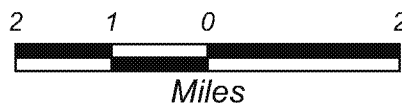
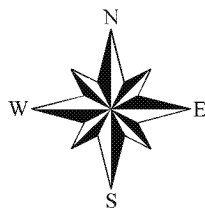
Table 1.2-1: Summary of Historic Exemption and Proposed Expansion by Area				
Current Exemption		Proposed Expansion		Description of Expansion
Formation	Interval/Sand	Formation	Interval/Sand	
<b>Central Area:</b>				
Siquoc	Siquoc <sup>1</sup>	Siquoc	Siquoc	Expand Area
		Monterey	Monterey	Add Monterey
<b>East Area:</b>				
Siquoc	Siquoc	Siquoc	Siquoc	Expand Area and consolidate Brooks with Siquoc
Siquoc	Brooks			
Monterey	Monterey	Monterey	Monterey	Expand Area
<b>West Area:</b>				
Siquoc	S1b	Siquoc	Siquoc	Expand Area and include all Siquoc Formation below the Upper Confining Layer
Siquoc	Los Flores (S9-S10)			
Monterey	Cherty Zone	Monterey	Monterey	Expand Area and include all Monterey Formation
<b>Siquoc Area:</b>				
Siquoc	Siquoc	Siquoc	Siquoc	Expand Area, consolidate Thomas and add Brooks in Siquoc
Siquoc	Thomas			
Monterey	Monterey	Monterey	Monterey	Expand Area
<b>Gato Ridge:</b>				
Siquoc	Siquoc	Siquoc	Siquoc	Expand Area
Monterey	Buff and Brown	Monterey	Monterey	Expand Area and include all Monterey formation
<b>Olivera Area:</b>				
Monterey	Cherty Bentonitic Buff and Brown	No Change	No Change	No Change
<b>Tinaquaic Area:</b>				
Monterey	Monterey	No Change	No Change	No Change

<sup>1</sup> In some interpretations of the 1973 Summary of Operation, only the basal Siquoc Formation below the Upper Confining Layer may have been exempted, however, the table of producing formations in the volume does not discriminate or call out any portion of the Siquoc Formation below the Upper Confining Layer. Since all of the Siquoc Formation below the Upper Confining Layer were known in 1973 to be oil productive, that is the interpretation being made in this Aquifer Exemption Expansion proposal.



## Legend

-  Study Area
-  1973-1974 Productive Boundary
-  Other Oilfield



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## CAT CANYON AQUIFER EXEMPTION EXPANSION

CURRENT  
AQUIFER EXEMPTION BOUNDARY

DATE: 10/17

FIGURE: 1.2-3

There are eight operators in the proposed Aquifer Exemption area:

- B.E. Conway Energy, Inc.
- ERG Resources, LLC
- Aera Energy , LLC
- Vaquero Energy, LLC
- Greka Oil and Gas, Inc.,
- California Resources Production Corporation
- RMR Energy Resources Inc., and
- Miocene Operating Services Inc.

A search of the water well data in the general area surrounding and including the study area shows that there are no municipal services company-owned water wells within the proposed Aquifer Exemption Expansion Area. No drinking water wells were found that were completed within the Study Area within the Sisquoc Formation below the Upper Confining Layer or Monterey Formation in the Cat Canyon Oil Field. Also, within the Study Area which extends at least one mile from the Aquifer Exemption Expansion Area there were no water wells for irrigation use completed in the Sisquoc Formation below the Upper Confining Layer or the deeper Monterey Formation. **Appendix 5-II, Water Well Completion Reports**

#### Community Service Water Wells

The proposed Aquifer Exemption Expansion Study Area covers a wide area with distinct oil field relationships to the nearby communities; Gato Ridge, which extends to the southeast of the main body of the field, is closer to Los Alamos Census-Designated Place, (CDP), while the remainder of the oil field areas are closer to the communities of Garey CDP and Sisquoc CDP, which are located inside the Cat Canyon Oil Field Administrative Boundary.<sup>2</sup>

The nearest municipal well to the proposed exemption area is (LACSD Well #5, No. 421002-007) located on Gonzalez Street in Los Alamos CDP, adjacent to the southern edge of the study area. There are also water wells serving as drinking water within the study area. Well #5 is 1000 feet deep and is located 8 miles from the centrus of the Cat Canyon Oil Field Aquifer Exemption study area, (Bernard, Letter to B. Falkenhagen, 2016), (Bernard, Los Alamos CDP, Director Public Works, 2017).

However, two other wells (4210002-003 and -004) are situated nearly equidistant, **Appendix 6-I, Treatment Feasibility Study**, (GeoTracker, 2017). A fourth well is identified as Well Name 4210002-002 which is in a remote agricultural location 1.4 miles from the nearest point of contact with the Community Service District (CSD) Boundary of the Los Alamos CDP was not reported as used for community service, (Bernard, Los Alamos CDP, Director Public Works, 2017).

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<sup>2</sup> CDP-Census Designated Place. These communities are not considered major communities but have some established community elements to warrant consideration in the context of census data.

**Table 1.2-2, Water Wells Serving Target Communities** identifies the nearest community service wells to the study area.

Table 1.2-2:Community Service Provider Water Wells Serving Target Communities					
Los Alamos CDP GeoTracker GAMA Community Well Locations <sup>3</sup>					
DATASET	WELL ID	WELL NAME	STREET	LATITUDE	LONGITUDE
DHS	W0604210002	4210002-003	Bell St.	34.74075	-120.27036
DHS	W0604210002	4210002-004	Price Ranch	34.73937	-120.26542
DHS	W0604210002	4210002-007	Gonzalez St.	34.74710	-120.28228
		420002-002			
Sisquoc CDP Community Well Locations <sup>4</sup>					
GSWC	Sisquoc #1	4200560-009	Foxen Cyn Rd.	34.864748	-120.29552
GSWC	No Facilities	4200560-001 and -007	Foxen Cyn. Rd	Same	Same

#### Gato Ridge Area

None of the community service provider's drinking water wells were found to be completed within the proposed aquifer exemption area in the Gato Ridge Area of the Cat Canyon Oil Field. The nearest community is in the Los Alamos CDP. The general distance to Los Alamos CDP from Gato Ridge Area centrus is 3.5 miles to the south by southeast.

#### Central, East, West and Sisquoc Areas

The community of Sisquoc is located inside the Aquifer Exemption Expansion Study Area. The community is served by Golden State Water Company which has currently inactive legacy wells within the community (which in turn is inside the proposed Aquifer Exemption Expansion Study Area). The community of Garey is served by individual residential wells, (no name given, 2017).

#### Agricultural Wells

There are agricultural water wells completed in the Careaga Formation and the Foxen Formation located above the Sisquoc Formation below the Upper Confining Layer' confining layer<sup>5</sup> and the Sisquoc Formation below the Upper Confining Layer oil sands.

#### Oil Field Service Wells

Several oil companies have operated water supply wells in the study area for purpose of steam generation in the productive areas. The oil field source water wells that serve steam programs in the oil Field surrounding the study area are listed in Section 5, Regional Hydrogeologic Setting, **Table 5.1-1, Water Well Inventory**.

<sup>3</sup> Per Los Alamos CDP, Utilities Manager

<sup>4</sup> Per Blochman SD Superintendent (D. Brown) and Golden State Water Company Annual Report Plant Facility Index.

<sup>5</sup> Certain water wells indicate they were drilled in to the top of the Sisquoc Upper Confining Layer. Data from these wells document the beginning of the thicker clay body that form the Upper Confining Layer.

### 1.3 Qualifications

WZI is a professional services consulting firm with experience in regulatory compliance and environmental engineering and geology. The members of WZI are Registered Professional Engineers, Professional Geologists and Certified Hydrogeologists. WZI expresses no opinion as to disciplines, subjects and practices outside those specifically enumerated above. Further, WZI expresses no opinion herein as to any matters of California or federal law. Resumes are included in **Appendix 1-I, Resumes**.

## 2 Applicant Information

### 2.1 Project/Field Name and Location

The Cat Canyon Oil Field is located approximately 3 miles north of the town of Los Alamos and approximately 3 miles east of City of Orcutt in Santa Barbara County, CA. The location of the proposed exemption expansion is the Monterey Formation and the Sisquoc Sand in the Cat Canyon Oil Field in:

T8N, R32W- Sections: 03, 04, 05, 06, 07, 08, 09, 10, 14, 15, 16, 22, and 23

T8N, R33W-Sections: 01, 02, and 12

T9N, R32W- Sections: 07, 18, 19, 20, 29, 30, 31, 32, and 33

T9N, R33W- Sections: 01, 02, 03, 04, 10, 11, 12, 13, 14, 15, 16, 21, 22, 23, 24, 25, 26, 27, 28, 34, 35, and 36

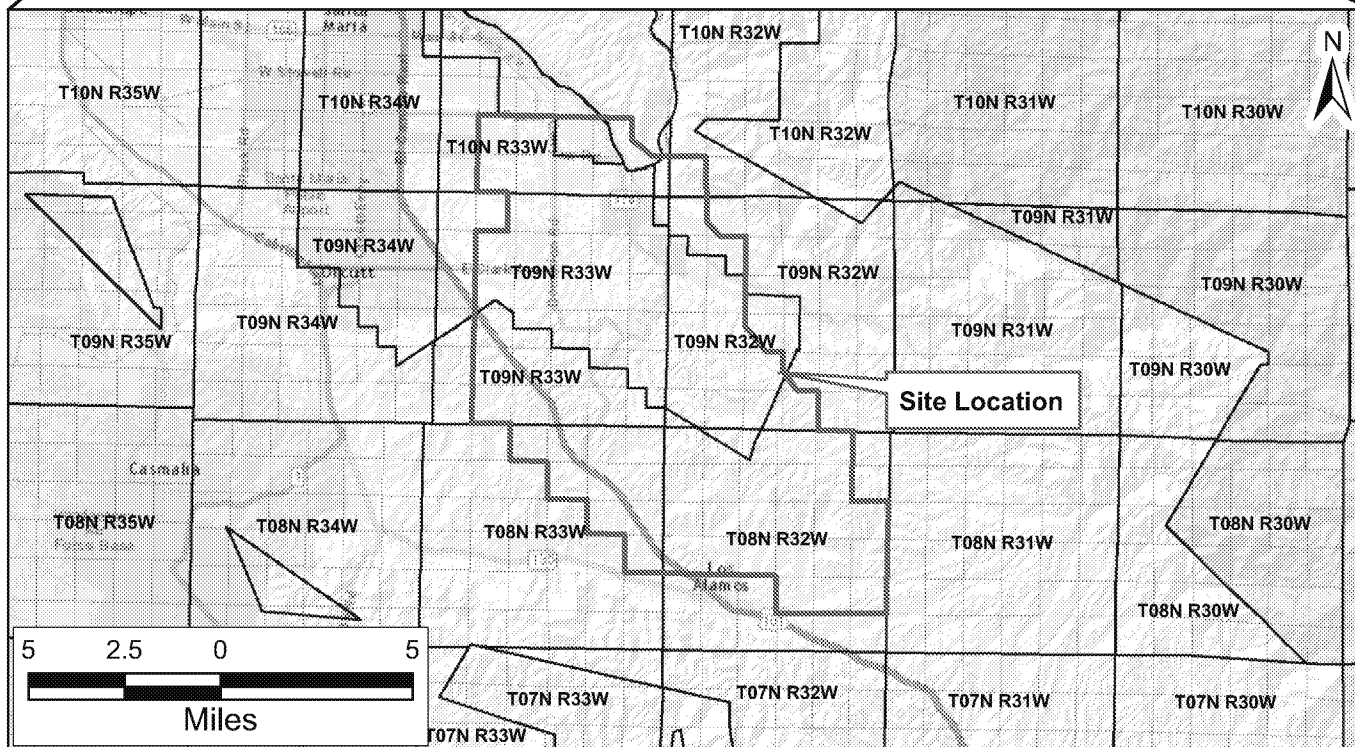
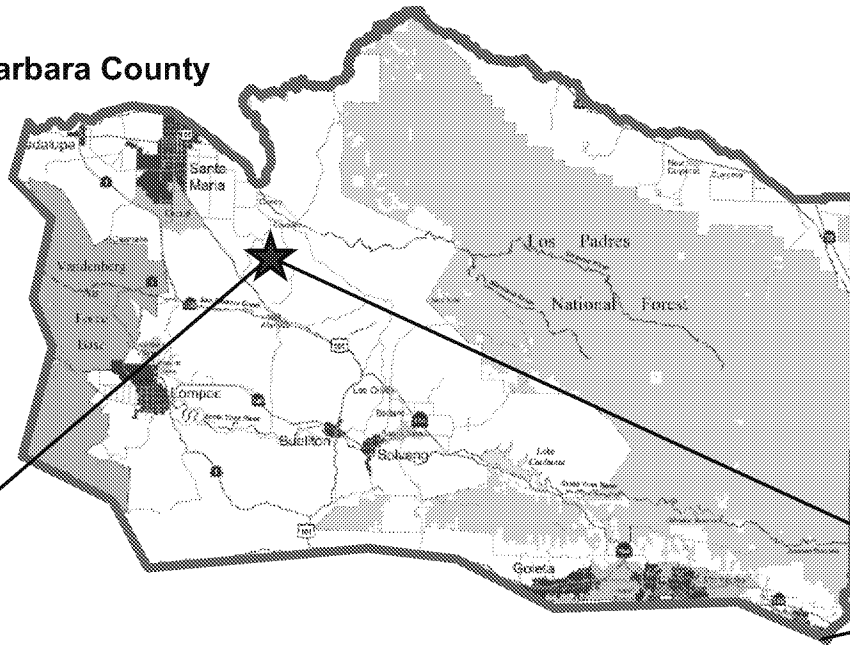
T10N, R33W- Sections: 33, 34, and 35

The location of the proposed Aquifer Exemption expansions for both formations is shown in **Figure 2.1-1, Location Map**.

### 2.2 Well Class and Purpose of Injection

The proposed exemption expansion is for Class II injection for enhanced recovery via steam injection and water flood, and reinjection of produced water and gas associated with the oil production.

# Santa Barbara County



	<b>WZI INC.</b> BAKERSFIELD, CALIFORNIA	
	<b>CAT CANYON AQUIFER EXEMPTION EXPANSION</b>	
	LOCATION MAP	
DATE: 7/17	FIGURE: 2.1-1	

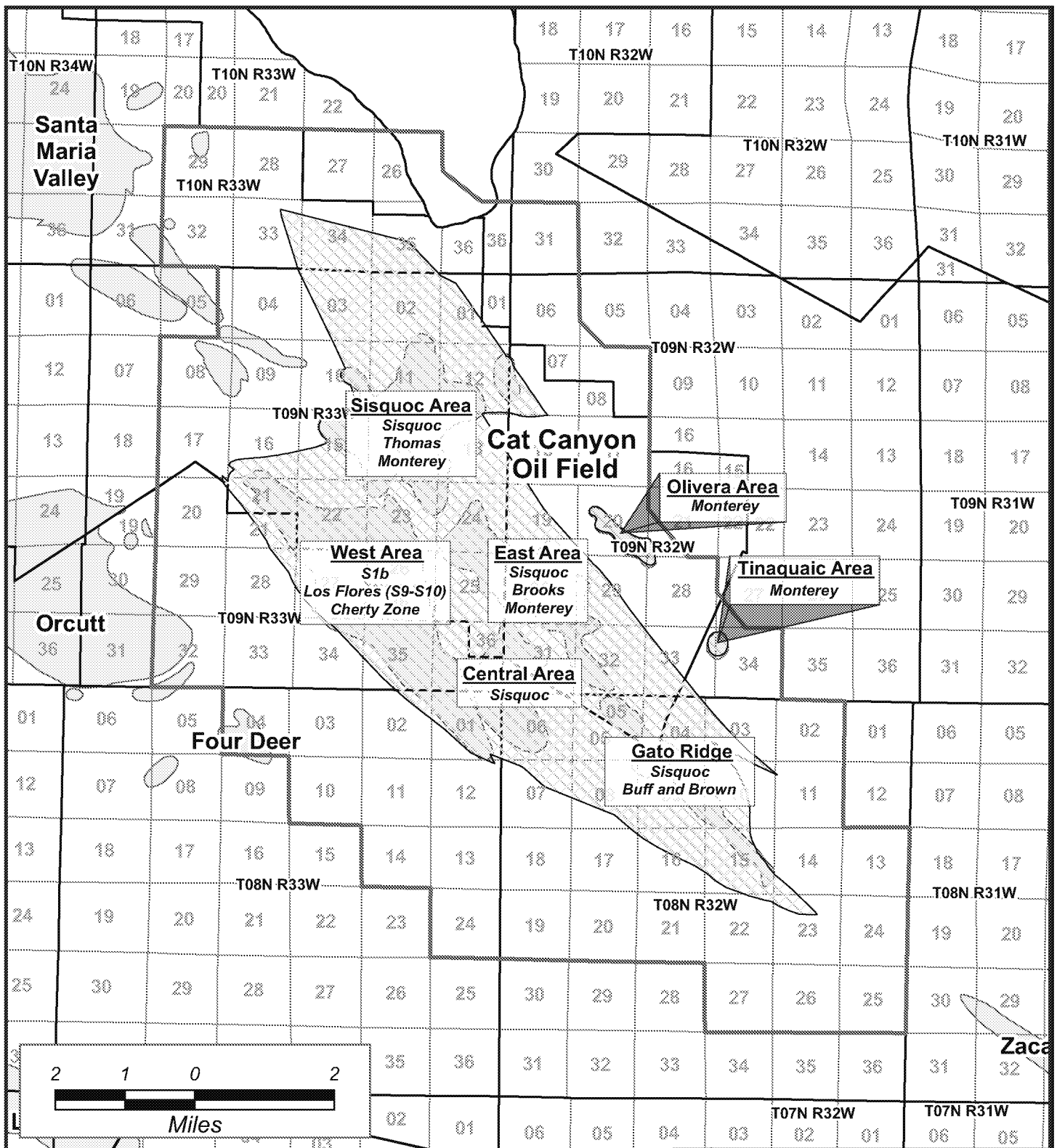
## 2.1 Areal Extent/Dimensions of Study Area

The proposed Aquifer Exemption Expansion boundaries encompasses the subject area's producing wells, as well as wells capable of commercial production, **Figure 1.2-1, Proposed Aquifer Exemption Boundary for Sisquoc Formation below the Upper Confining Layer** and **Figure 1.2-2, Proposed Aquifer Exemption Boundary for Monterey Formation** .

### Study Area

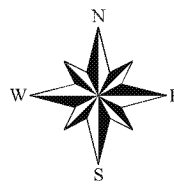
The study area extends at least 1-mile from the proposed Aquifer Exemption Expansion boundaries; for ease of review the study area delineation is conservatively extended to the closest section line outside of the 1-mile radius from the proposed exemption boundaries in all directions.

The combined study area which includes the proposed Aquifer Exemption Expansion areas for Monterey Formation and Sisquoc Formation below the Upper Confining Layer was chosen in order to delineate the extent of the productive area, to quantify the number and the location of any and all water wells which could potentially have been drilled into the formations proposed for exemption, and to delineate the confinement of the zone proposed for expansion of the exemption. The radius of review/ the study area was determined to be greater than one mile from the pinchout of the Sisquoc Formation sands below the Upper Confining Layer or at least one mile beyond the point at which Sisquoc Formation water quality [TDS] exceeds 10,000mg/L and is no longer defined as a USDW. In addition, the radius of review/study area was determined to be at least one mile from the lowest known potentially producible oil containing strata of the Monterey Formation and Sisquoc Formation below the Upper Confining Layer or the sealing fault controlling the eastern extent of the Monterey production horizon in Cat Canyon Oil Field. The study area is shown on **Figure 2.1-2, Study Area Location Map**.



## Legend

- Study Area
- Proposed Siquoc Aquifer Exemption Boundary
- Proposed Monterey Aquifer Exemption Boundary
- 1973-1974 Productive Boundary
- Other Oilfield



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BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

STUDY AREA LOCATION MAP

DATE: 10/17

FIGURE: 2.1-2

The study area for the water well research was based on USEPA, Guidance 34 and the geology specific to the area around the Cat Canyon Oil Field. The area of review was specifically defined by a progression of study increments listed below:

1. Gather water well data from Department of Water Resources (DWR), and other data sources;
2. Define the water recharge areas for the ground water supply wells;
3. Define ground water barriers based on literature search;
4. Define potential depth of the aquifers being studied for exemption; and
5. Plot and examine all water supply wells within an area where the aquifers are proposed for exemption to make a determination as to whether or not the proposed exemption aquifer was currently being utilized or had in the past been utilized as a source of water supply.

#### Study Increment 1:

The water well area of review for which water well data were obtained encompassed a 37,000 foot radius (7 miles) in GAMA from the center of the study area, **Figure 2.1-2, "Study Area Location Map"**; this 77 square mile area (77 sections) encompassed the entire study area as well as numerous whole sections outside of and directly East, West, North and South of the defined Study Area. Water well records were obtained from the Department of Water Resources and Santa Barbara County. An online record search was conducted of the State Water Resources Control Board GeoTracker GAMA well locations. In addition to the former data sources, the Department of Water Resources and USGS publications were consulted. (Department of Water Resources, 1998), (Muir, 1964), (Worts & Thomasson, 1951).

#### Study Increment 2:

The Aquifer Exemption Study Area is located on the northern edge of the San Antonio Ground Water Basin and the Southwest end of the Santa Maria Ground Water Basin, **Figure 5.1-1, Hydrogeologic Basin Map**. The Study Area is split by the Cat Canyon and Gato Ridge anticlines which run from the northwest to the southeast. In the southwest half of the Study Area there are numerous southwest drainages that discharge into the San Antonio Creek in the San Antonio Groundwater Basin. The northeastern part of the study area drains into Cat Canyon Creek (and several minor canyon drainages) which feed into the Sisquoc River in the Santa Maria Groundwater Basin. The potential recharge areas were defined by the surface geologic map, **Figure 4.1-2, Dibblee Surface Geology Map**. The Monterey out crops to the east-southeast, The Sisquoc confining clay outcrops in the very southeastern end of the Study Area with limited potential for recharge into Sisquoc Formation below the Upper Confining Layer due to the clay in the Upper Confining Layer and the pinch out of the Sisquoc Formation below the Upper Confining Layer themselves.

#### Study Increment 3:

The area was further defined by character of the ground water in the area. The deposits containing the water being utilized in proximity to Cat Canyon Oil Field are of recent to Pliocene age. The depths of the water wells vary from less than 100 feet in the Alluvium along the drainage areas to approximately 1000 feet in the confined/semi confined aquifers to the west that are Pliocene in age. In the southwestern portion of the Study Area, the movement of the ground water in both zones was from the structural ridge formed by Gato Ridge and Cat Canyon

Anticline southwest toward the axial trough of the San Antonio Groundwater Basin to the southwest. In the northeastern portion of the Study Area, the movement of groundwater in both zones was from the structural ridge formed by Gato Ridge and Cat Canyon Anticline west toward the axial trough of the Santa Maria Groundwater to the northwest. The source of recharge to these shallow aquifers is from the surface recharge from minor streams. The study area is bordered by Purisma Hills to the south, and the Sierra Madre Range to the east and north, (Bradley & al, 1943), (Department of Water Resources, 1998), (Hutchinson, 1980), (Worts & Thomasson, 1951).

Study Increment 4 and 5:

The water wells gathered in Increment 1 were mapped within the area and plotted on the geologic cross sections in Section 5, Regional Hydrogeologic Setting:

**Figure 5.1-4 Cross Section A-A' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-5 Cross Section B-B' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-6 Cross Section C-C' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-7a Cross Section D-D' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-7b Cross Section D'-D'' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-8 Cross Section E-E' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-9 Cross Section F-F' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-10 Cross Section G-G' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-11 Cross Section H-H' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-12 Cross Section I-I' with water wells and total proposed aquifer exemption areas;**

**Figure 5.1-13 Cross Section J-J' with water wells and total proposed aquifer exemption areas; and**

**Figure 5.1-14 Cross Section K-K' with water wells.**

The confinement in the study areas to both the northeast and southwest were defined by the depth of the water wells and the depth of the base of the Confining Zone of the Upper Sisquoc Clay/Foxen Clay by determination that the base of the confining zone was well below the base of the deepest irrigation water source well. Refer to **Figure 5.1-6, Cross Section C-C' with water wells and total proposed aquifer exemption areas** and **Figure 5.1-14, Cross Section K-K' with water wells**.

The water well review area was thus defined as greater than 1 mile from the proposed Aquifer Exemption Expansion Area of Cat Canyon Oil Field. The nearest municipal well to the proposed

exemption area is (LACSD Well #5, No. 421002-007) located on Gonzalez Street in Los Alamos CDP, adjacent to the southern edge of the study area. There are also water wells serving as drinking water within the study area. Well #5 is 1000 feet deep and is located 8 miles from the center of the Cat Canyon Oil Field Aquifer Exemption study area, (Bernard, Letter to B. Falkenhagen, 2016), (Bernard, Los Alamos CDP, Director Public Works, 2017).

## 2.2 Names and Addresses of each applying Owner/Operator

BE Conway Energy, Inc.  
PO Box 2050  
Orcutt, CA 93457

Vaquero Energy, LLC  
PO Box 2050  
Orcutt, CA 93457

ERG Operating Company, LLC  
6085 Cat Canyon Road  
Santa Maria, CA 93454-9109

Aera Energy LLC  
10000 Ming Avenue  
Bakersfield, CA 93311

## 3 Regional Setting

The Study Area for the proposed Aquifer Exemption Expansion for the Cat Canyon Oil Field is located in portions of Township 10 North, Range 33 West; Township 10 North, Range 32 West; Township 9 North, Range 33 West; Township 9 North, Range 32 West; Township 8 North, Range 33 West, and Township 8 North, Range 32 West, in Santa Barbara County, California as shown on **Figure 2.1-1, Location Map**, centered on Lat. 34.8411° and Long. -120.3130°. The nearest communities within the study area are Garey CDP and Sisquoc CDP; other communities in proximity are Los Alamos CDP and the City of Orcutt.

### 3.1 Land Use

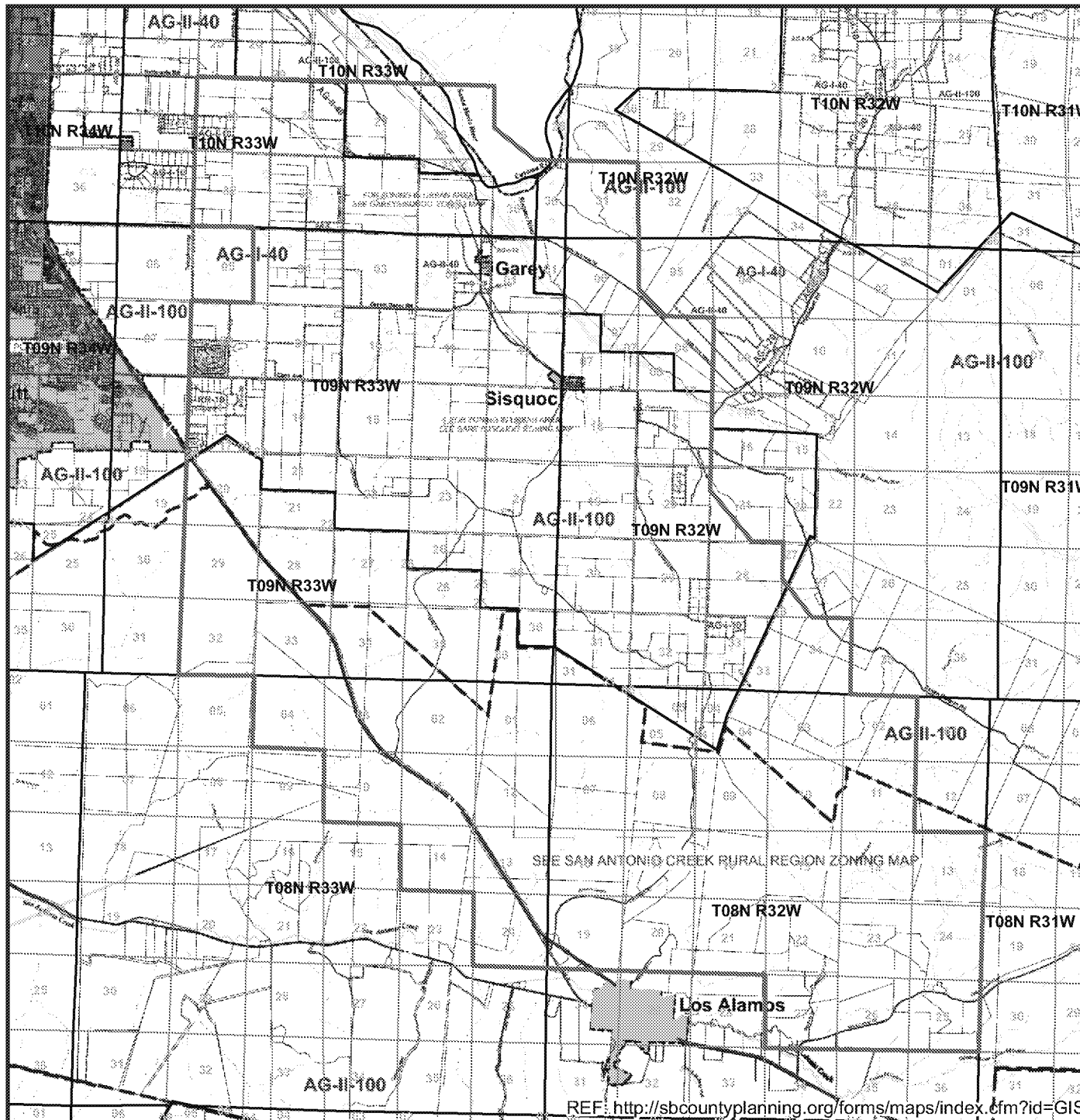
#### 3.1.1 Santa Barbara County General Plan and Zoning

The County of Santa Barbara in which the Cat Canyon Oil field is located has General Plan and Zoning authority over the study area (Development, Comprehensive Plan, 2017). The Petroleum Unit regulates onshore oil and gas activities within Santa Barbara County by performing annual inspections of onshore production and injection wells, processing and storage facilities, pipelines and other pertinent equipment throughout oil production leases. Regulation of onshore petroleum facilities and operations includes but is not limited to: exploration; production; storage; processing; transportation; disposal; plugging and abandonment of wells; and of operations and equipment, (County S. B.).

The Santa Barbara County Zoning is shown on **Figure 3.1-1, Santa Barbara County Zoning Map**. The surrounding land use is primarily agricultural: AG-II-40, AG-II-60, AG-II-100 and AG-II-320. Oil and gas exploration and production use is consistent with these AG designations. The communities of Garey CDP and Sisquoc CDP have urban designation within their special planning areas, Appendix 3-III, Garey and Sisquoc Zoning.

#### 3.1.2 Farm Land of State-Wide Importance

A review of the state designations of farm land was conducted. There are small areas of prime farmlands of state-wide importance and unique farmlands within the proposed Aquifer Exemption Expansion Area as shown on **Figure 3.1-2, Farmlands of State-Wide Importance**. (Conservation).



## Legend

Study Area

### ZONING LEGEND:

AG-I-5: Ag Land, 5 acre min.  
 AG-I-10: Ag Land, 10 acre min.  
 AG-I-20: Ag Land, 20 acre min.  
 AG-I-40: Ag Land, 40 acre min.  
 AG-II-40: Rural Ag Land, 40 acre min.  
 AG-II-100: Rural Ag Land, 100 acre min.  
 AG-II-320: Rural Ag Land, 320 acre min.

Region Boundary  
 Coastal Zone Boundary  
 Rural Boundary (from Comprehensive Plan)  
 Zoning Boundary  
 Incorporated City  
 Unincorporated Urban Area (from Comp. Plan)  
 Vandenberg Air Force Base  
 Community Plan Boundary



2 1 0 2  
 Miles



**WZI INC.**

BAKERSFIELD, CALIFORNIA

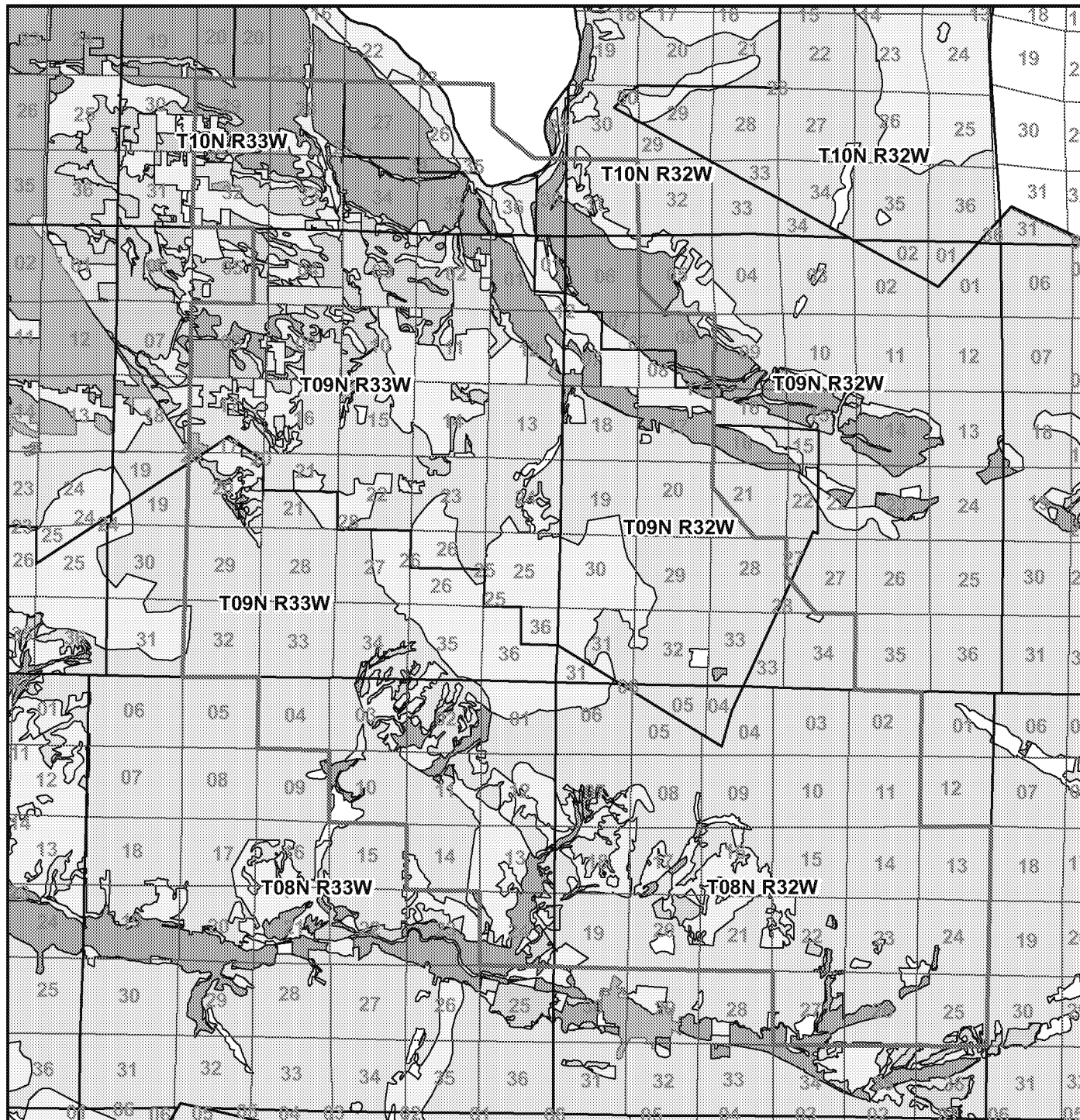
**CAT CANYON AQUIFER  
 EXEMPTION EXPANSION**

SANTA BARBARA COUNTY  
 ZONING MAP

REF: <http://sbcountyplanning.org/forms/maps/index.cfm?id=GIS>

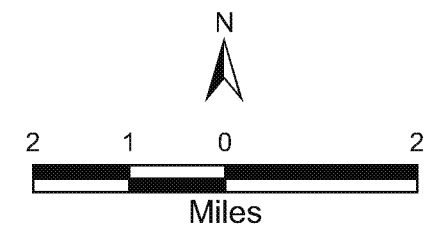
DATE: 7/17

FIGURE: 3.1-1



# Legend

- Study Area
- Farmlands of Statewide Importance**
  - Prime Farmland
  - Farmland of State Wide Importance
  - Unique Farmland
  - Farmland of Local Importance
  - Grazing Land
  - Urban and Built Up Land
  - Other Land
  - Water



**WZI INC.**  
BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

**FARMLANDS OF STATE-WIDE  
IMPORTANCE**

DATE: 7/17

FIGURE: 3.1-2

### 3.1.3 Topography

The topography within the study area is semi-mountainous terrain and varies from a low of less than 600 feet above sea level to a high over 1200 feet above sea level. The topographic map of the area is shown on **Figure 3.1-3, Topographic Map**. (U.S. Geological Survey, 2015)

### 3.1.4 Regional Municipal Water Use Patterns

A detailed discussion of regional water is contained **Appendix 6-I, Treatment Feasibility Study. Table 3.1-1, Water Required to Meet Projected Demands** shows the water deliveries made by the Water Purveyors associated with DAU 71, 73 and 76 in their respective service territory. Los Alamos Community Services District, (LACSD), will continue to use ground water to follow their forecast 268 acre feet of demand at \$35/acre feet (this price is similar to the projected cost of water for agricultural purposes). Los Alamos CSD does not show any net water needed by 2025. Ground water will continue to be the primary source of water for M&I and the regional net water needed (based on Private M&I) is 20,664 acre feet. LACSD response concerning possible oilfield sourcing of produced water as an alternative to normal sources indicates that ratepayer willingness to pay for incremental facilities was tested and found to be low, consistent with EPA's study, (Bernard, Letter to B. Falkenhagen, 2016). Refer to Appendix III of the Treatment Feasibility Study, Appendix 6-I.

Water supplies in the San Antonio Valley are mainly derived from groundwater; some importation of State Water Project supplies occurs and is delivered to the service area of Vandenberg Air Force Base within DAU 73. The sources of groundwater recharge are rainfall and stream flow in Los Alamos Creek which drains the valley and flows intermittently. No significant impoundments occur on Los Alamos Creek or its tributaries. The Los Alamos Community Services District, (LACSD), supplies water from wells to the community of Los Alamos. Water supplied by the LACSD is approximately 1.5 percent of the water currently used in DAU 73. The San Antonio Basin underlies approximately 70,400 acres and is comprised of alluvium and semi-consolidated sands and gravels (Paso Robles Formation). This basin is utilized by agriculture and the LACSD. Vandenberg AFB has back-up wells in the westernmost portion of the basin, but production from those wells has fallen over 90 percent since importation of State Water Project supplies. The Santa Barbara County Water Agency reports the current safe yield estimate as approximately 15,000 acre feet per year (AFY).

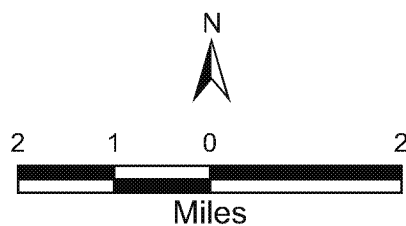
**Table 3.1-1**  
**Water Required to Meet Projected Demand, ac-ft**

DAU and Subareas	2010				2015				2020				2025			
	Total Available	Total Demand	Total Return Flows	Net Water Needed*	Total Available	Total Demand	Total Return Flows	Net Water Needed	Total Available	Total Demand	Total Return Flows	Net Water Needed*	Total Available	Total Demand	Total Return Flows	Net Water Needed
<b>DAU 71:</b>																
City of Santa Maria	16,354	13,072	9,422		16,243	16,223	11,708		16,132	15,600	11,273		16,022	16,100	11,637	
Golden State Water Co.	2,247	6,594	1,627		2,244	8,295	2,051		2,241	7,634	1,891		2,237	7,879	1,961	
City of Guadalupe	382	930	209		378	1,004	226		375	1,094	246		371	1,194	269	
Private SMV, M&I and Ag		101,852	18,333			101,852	18,333			101,852	18,333			101,852	18,333	
Casmalia CSD	-	9	-		-	9	-		-	9	-		-	9	-	
<b>Santa Maria Totals</b>	86,983	122,457	29,592	5,882	86,865	127,383	32,318	8,200	86,748	126,189	31,743	7,698	86,630	127,034	32,200	8,204
<b>DAU 73:</b>																
Los Alamos CSD	-	275	62		-	270	61		-	261	59		-	268	60	
Private San Ant. M&I, Ag		33,168	4,312			33,168	4,312			33,168	4,312			33,168	4,312	
<b>San Antonio Totals</b>	9,000	33,443	4,374	20,069	9,000	33,438	4,373	20,065	9,000	33,429	4,371	20,058	9,000	33,436	4,372	20,064
<b>DAU 76:</b>																
Cuyama CSD		146	56			142	55			139	54			142	55	
Private Cuyama Valley M&I, Ag		37,987	6,838			37,987	6,838			37,987	6,838			37,987	6,838	
<b>Cuyama Valley Totals</b>	216,944	38,133	6,894	24,295	7,102	38,129	6,892	24,134	17,260	38,126	6,891	23,975	17,425	38,129	6,892	23,812



### Legend

- Study Area
- 500ft Contours



**WZI INC.**  
BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

TOPOGRAPHIC MAP

DATE: 7/17

FIGURE: 3.1-3

### 3.2 History of the Cat Canyon Oil Field

The Cat Canyon Oil Field consists of five main producing areas: Sisquoc Area, West Area, Central Area, East Area and Gato Ridge Area. The first discovery of oil was in the West Area with the completion of Palmer No. 1 in 1908 for 600 to 10,000 barrels per day from the Sisquoc Formation below the Upper Confining Layer. Active prospecting of the well-defined Gato Ridge anticline was under way by 1911. Practically all the early wells encountered shows of heavy oil and a few produced a small amount. Barnsdall-Rio Grande Oil Co. Tognazzini No. 1 (now Barnsdall Oil Co. Tognazzini No. 1), completed in 1931 with a daily yield of 1,100 barrels of 13° (API) oil, was the first commercially successful well in the Monterey in Cat Canyon Oil Field. The oil in Cat Canyon Oil Field is heavy, 7° to a 13° API with occasional Monterey Formation production exceeding 20° API. By 1957, the Monterey Formation in the Gato Ridge Area was recognized as one of the important naturally fractured reservoirs in the United States and all of the five Producing Areas had been discovered and partially developed in both the Monterey Formation and the Sisquoc Formation below the Upper Confining Layer, (Bradley & al, 1943), (Hubbert & Willis, 1955). Reinjection of produced water and gas has taken place since the early 1960s, along with steaming and attempts at fire flooding due to the heavy oil gravity. **Figure 3.2-1, Cat Canyon Production History**, shows the production and injection history of Cat Canyon Oil Field since 1977. **Appendix 5-V, Fluid Level Data and Material Balance Calculations**, contains a list of wells by API number and the production and injection by well. Currently, the Cat Canyon Oil Field has produced approximately 311 million barrels of oil and 1.45 billion barrels of water with the recorded water injection of 868 million barrels as steam, water flood and reinjection. There are limited records of the gas injection due to lack of metering because of lack of gas sales.

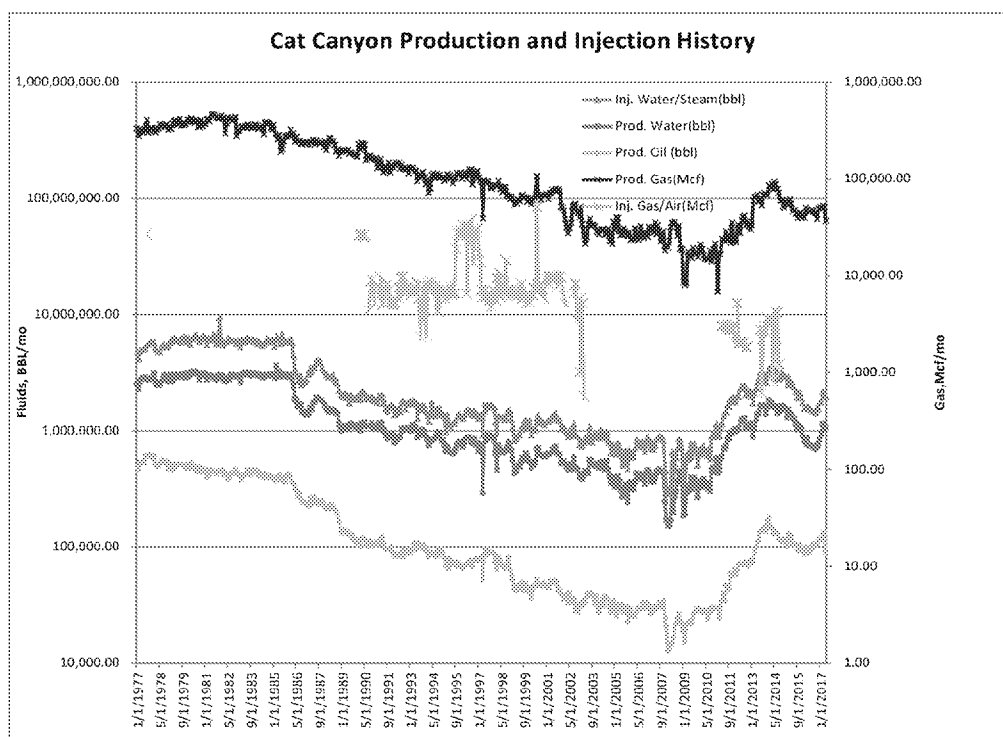


Figure 3.2-1

This proposed Aquifer Exemption Expansion is for the Monterey Formation and Siquoc Formation below the Upper Confining Layer for which the productive area has been extended since the original Aquifer Exemption for the Monterey Formation and Siquoc Formation below the Upper Confining Layer was granted by USEPA in 1982.<sup>6</sup> In 1982, USEPA, the State Water Resources Control Board and the Division entered into a Memorandum of Agreement concerning the implementation of the Underground Injection Control program for Class II wells.

**Table 3.2-1, Summary of Historic Exemption**, shows the status of the Areas and formations at the time of the MOA.

<b>Table 3.2-1: Summary of Historic Exemption</b>	
<b>Current Exemption</b>	
<b>Formation</b>	<b>Interval/Sand</b>
<b>Central Area:</b>	
Sisquoc	Sisquoc
<b>East Area:</b>	
Sisquoc	Sisquoc
Sisquoc	Brooks
Monterey	Monterey
<b>West Area:</b>	
Sisquoc	S1b
Sisquoc	Los Flores (S9-S10)
Monterey	Cherty Zone
<b>Sisquoc Area:</b>	
Sisquoc	Sisquoc
Sisquoc	Thomas
Monterey	Monterey
<b>Gato Ridge:</b>	
Sisquoc	Sisquoc
Monterey	Buff and Brown
<b>Olivera Area:</b>	
Monterey	Cherty Bentonitic Buff and Brown
<b>Tinaquaic Area:</b>	
Monterey	Monterey

<sup>6</sup> Sept 1982 Memorandum of Agreement (MOA) – Attachment #2. Exempted 1425 Demonstration Aquifers: “All oil and gas producing aquifers identified in Volumes I, II, and III of the California Oil and Gas Fields submitted in the 1425 Demonstration dated April 20, 1981 are exempted.” In 1988 the State Water Resources Control Board entered into a Memorandum of Agreement with the Department of Conservation codifying the process for implementation of the UIC program.

The following cross sections show the current aquifer exemption areas and formations and the total proposed aquifer exemption areas:

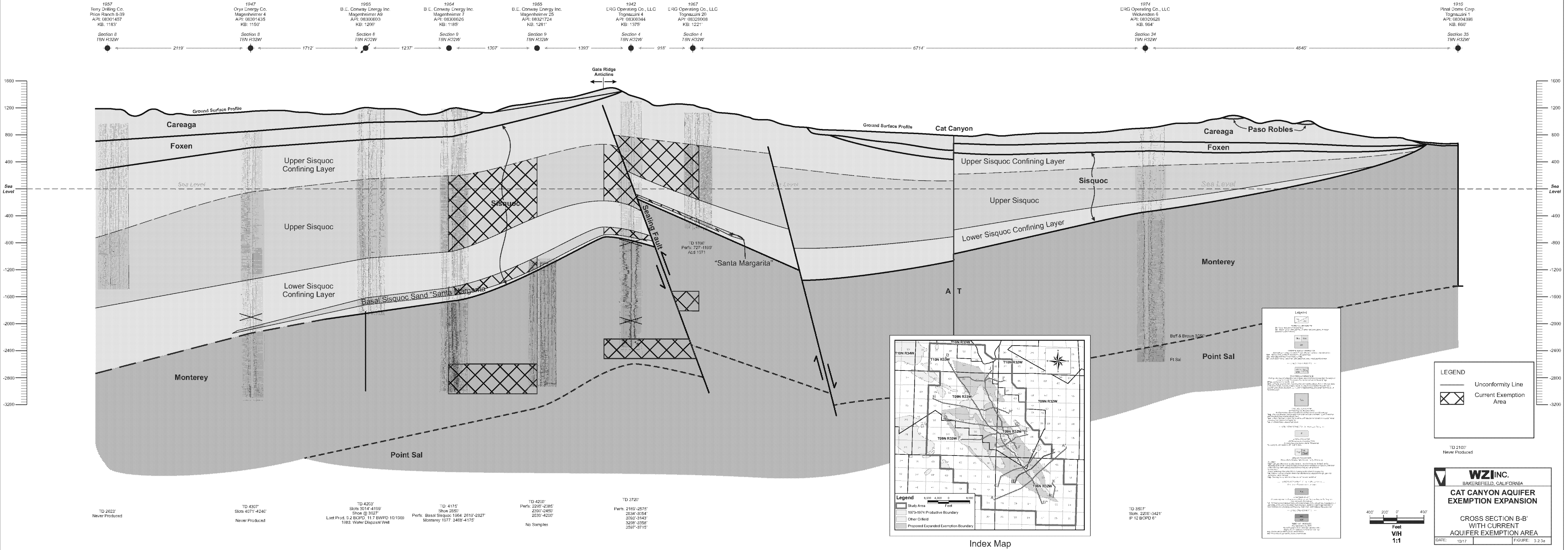
**Figure 3.2-2a and b Cross Section A-A' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-3a and b Cross Section B-B' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-4a and b Cross Section C-C' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-5aa and ab Cross Section D-D' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-5ba and bb Cross Section D'-D'' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-6a and b Cross Section E-E' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-7a and b Cross Section F-F' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-8a and b Cross Section G-G' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-9a and b Cross Section H-H' with current aquifer exemption area and total proposed aquifer exemption area;**  
**Figure 3.2-10a and b Cross Section I-I' with current aquifer exemption area and total proposed aquifer exemption area; and**  
**Figure 3.2-11a and b Cross Section J-J' with current aquifer exemption area and total proposed aquifer exemption area.**





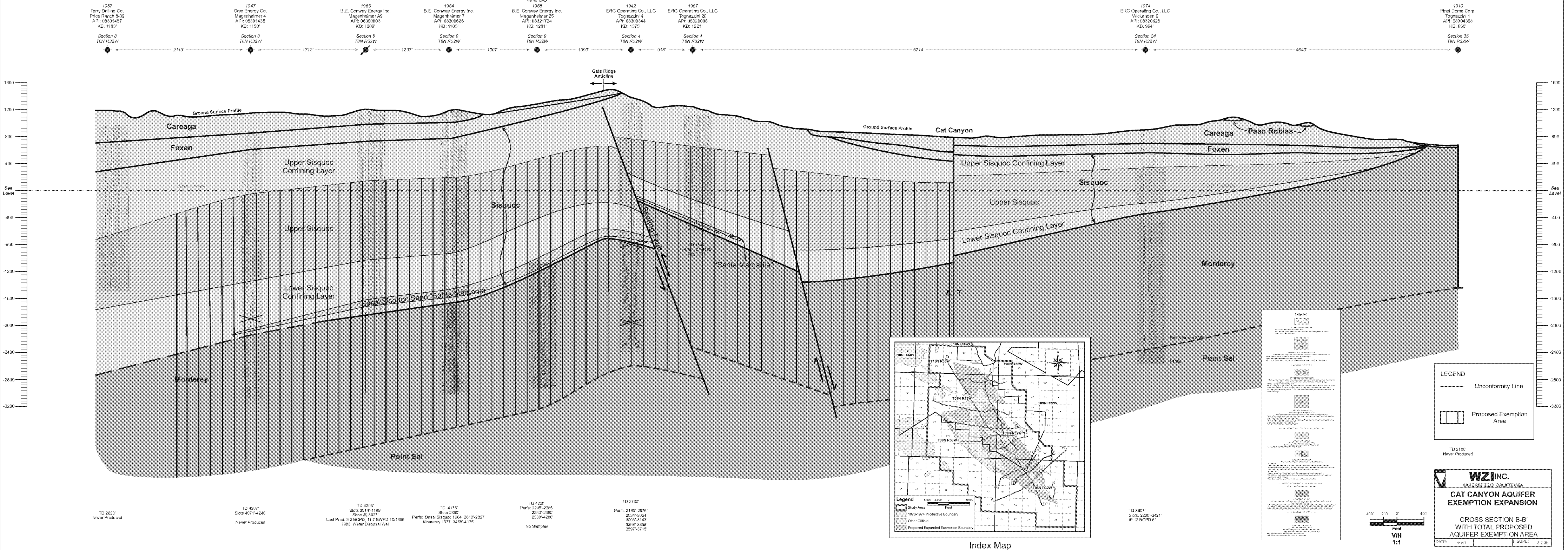
Southwest  
B

Northeast  
B'



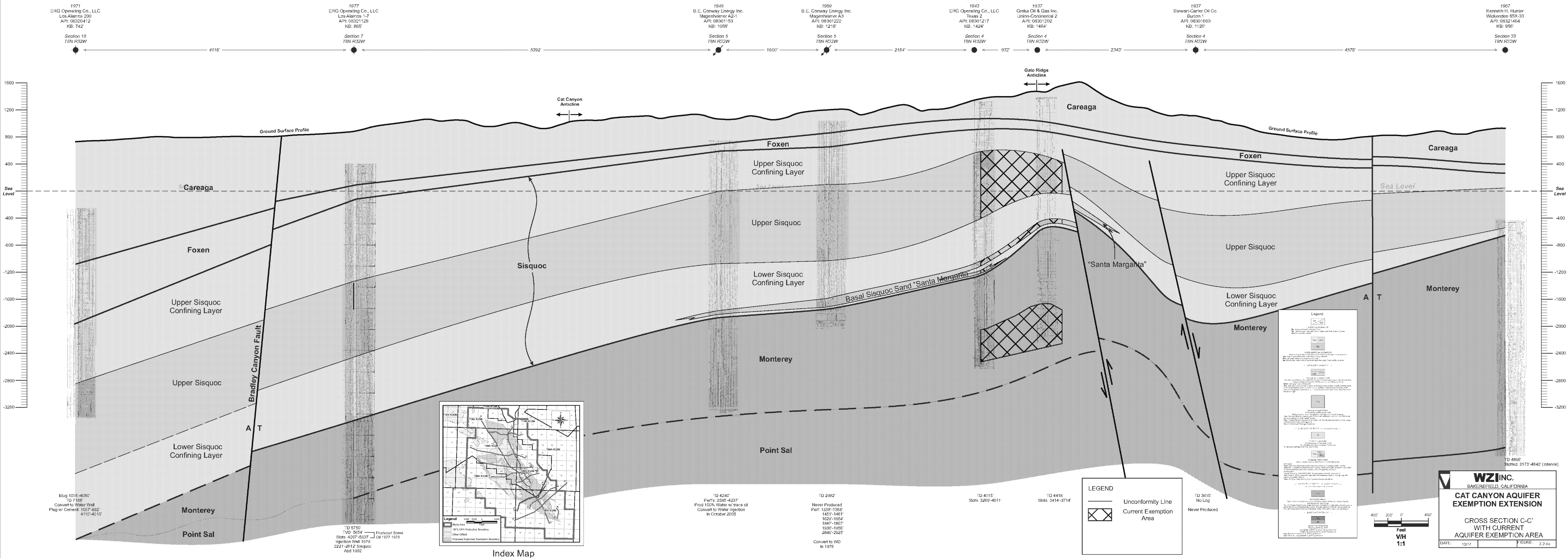
Southwest  
B

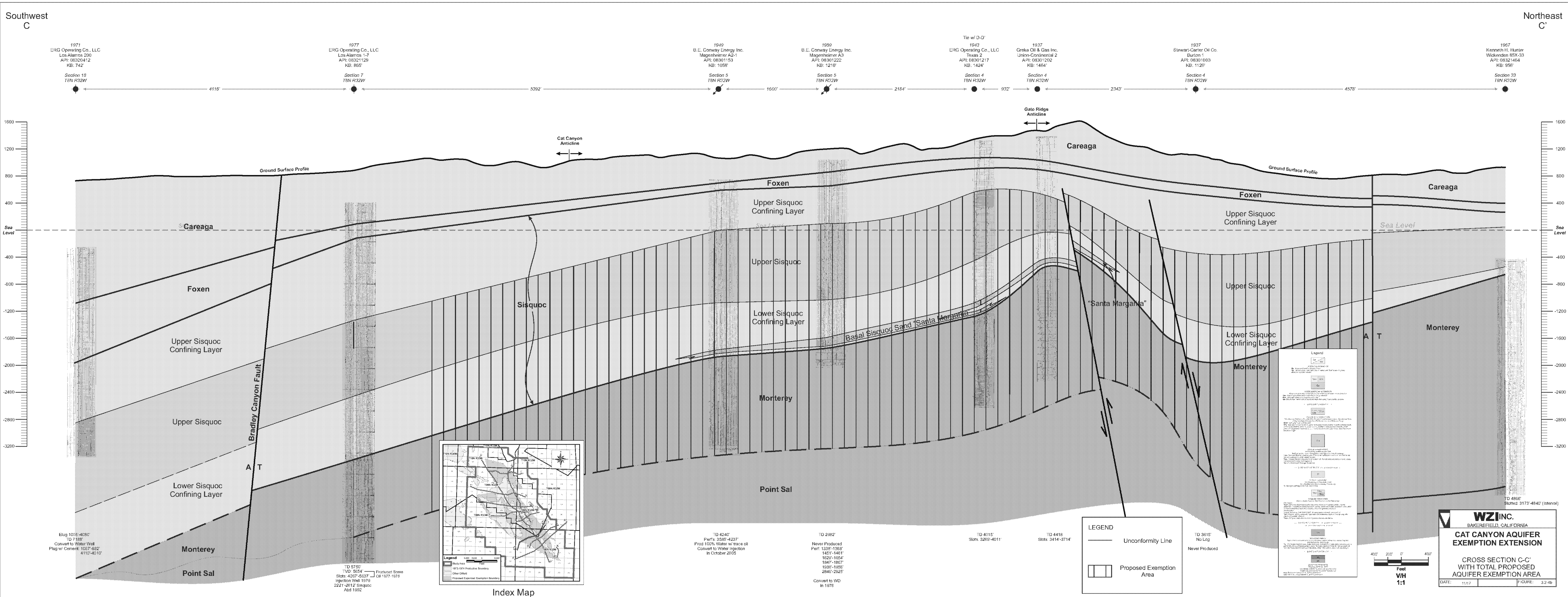
Northeast  
B'



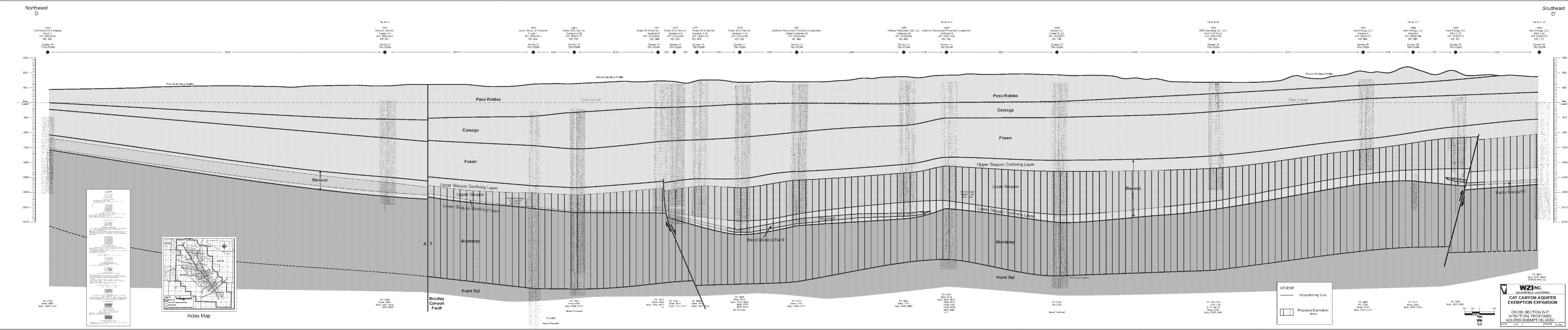
Southwest  
C

Northeast  
C'



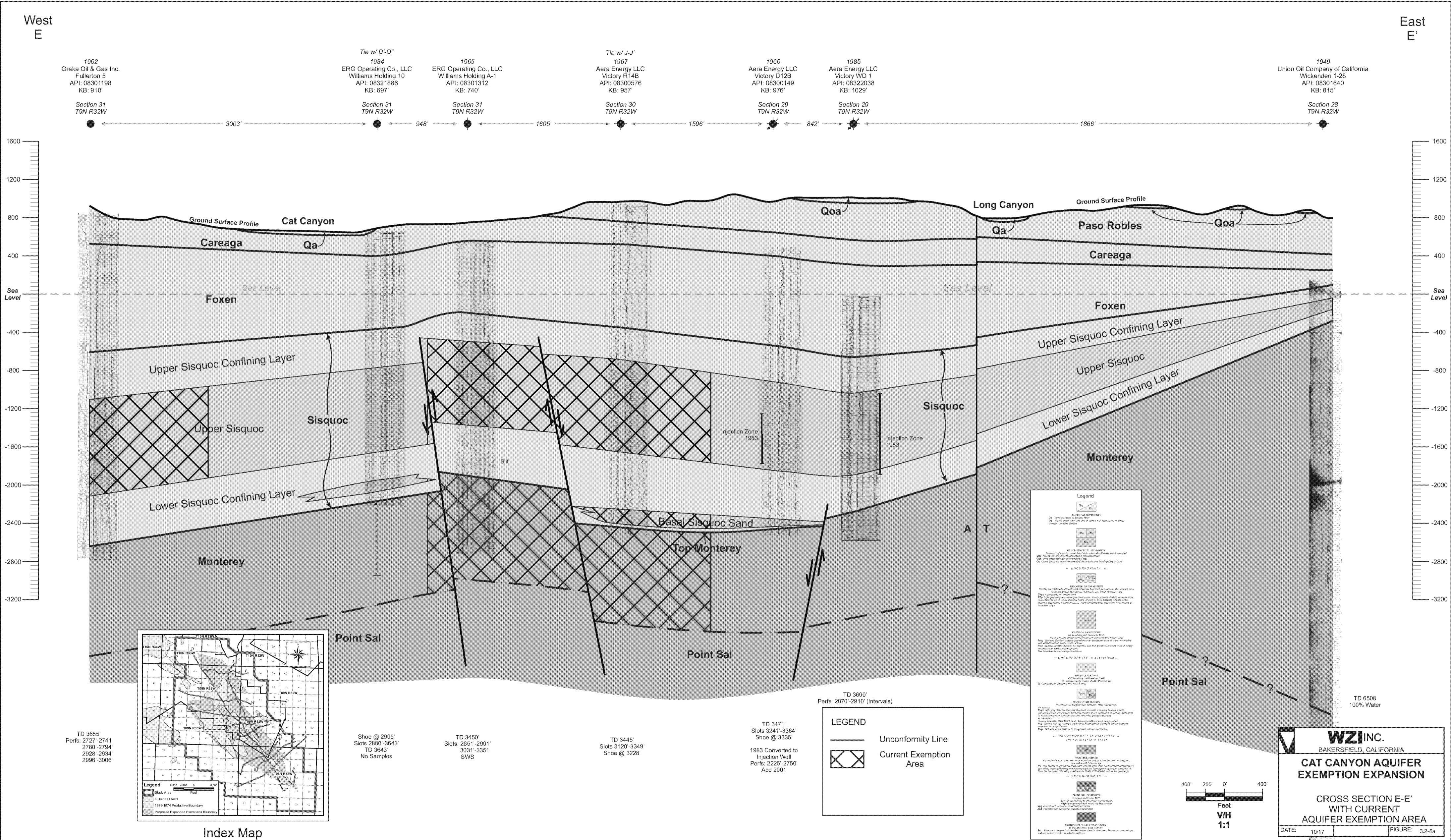


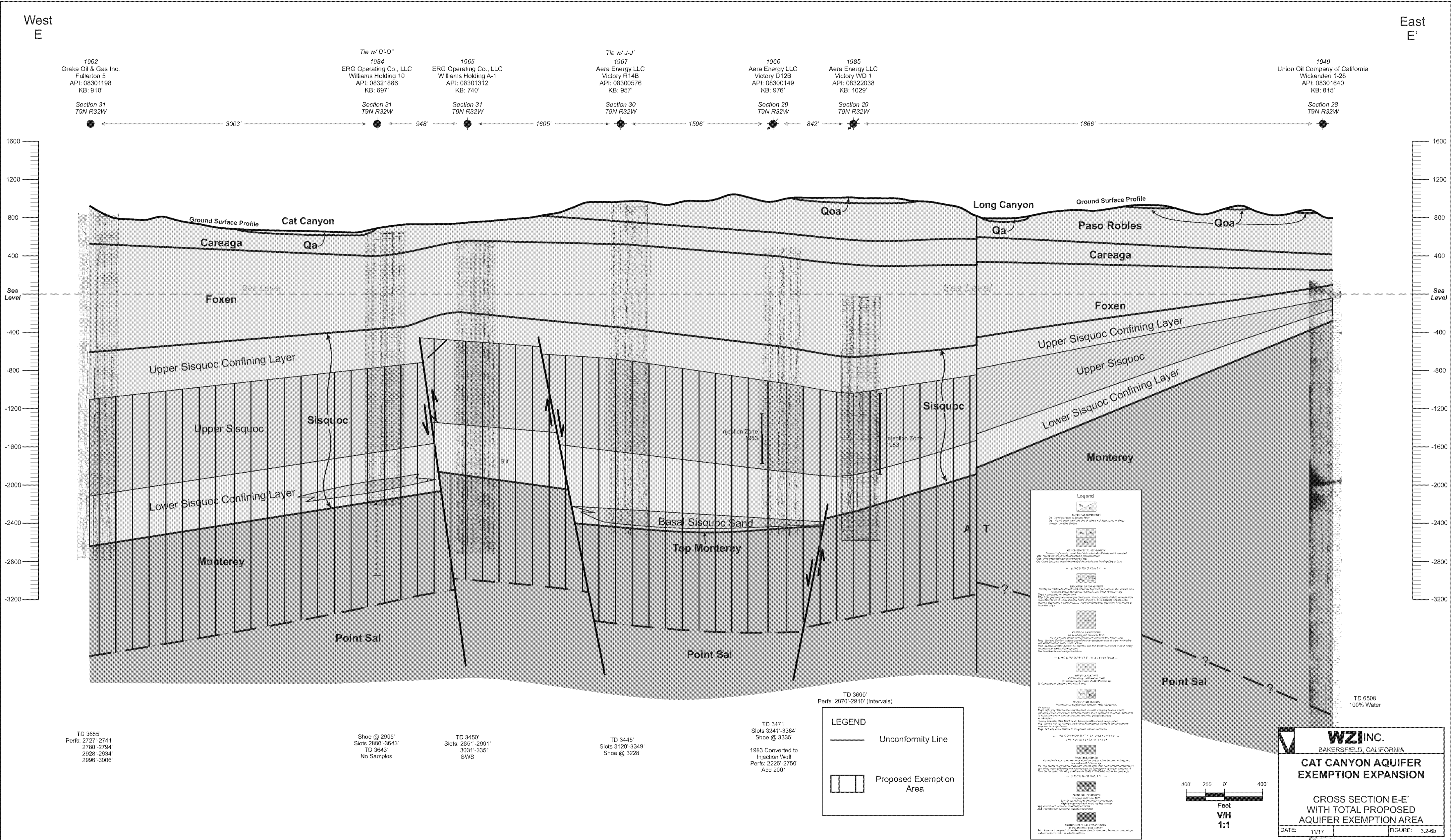


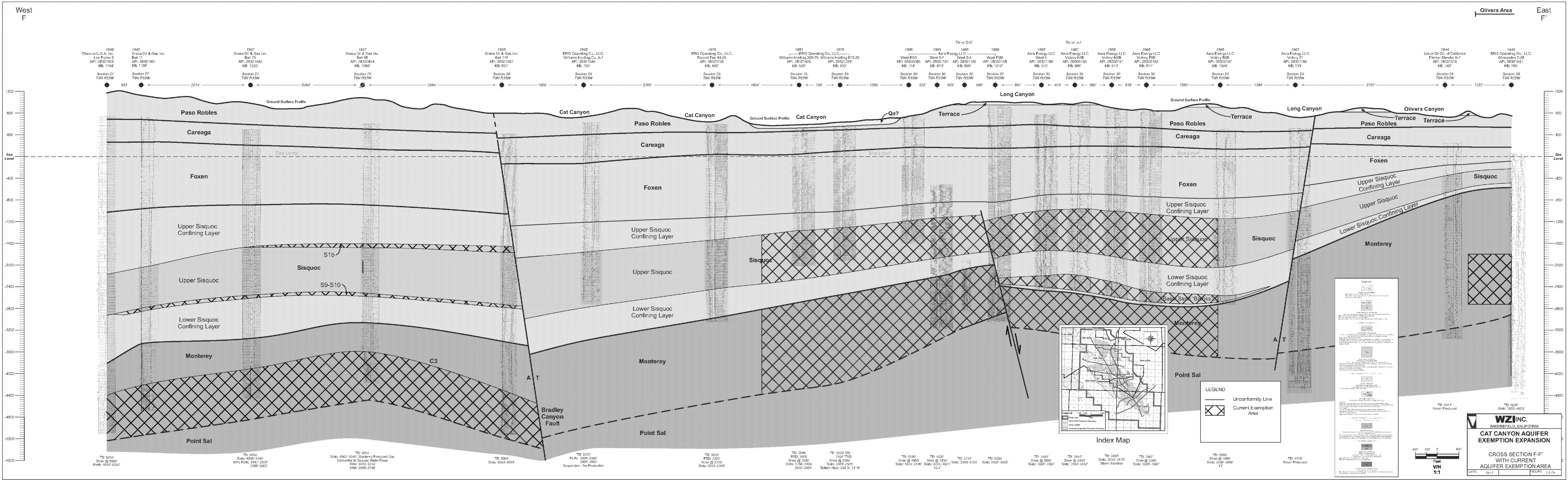


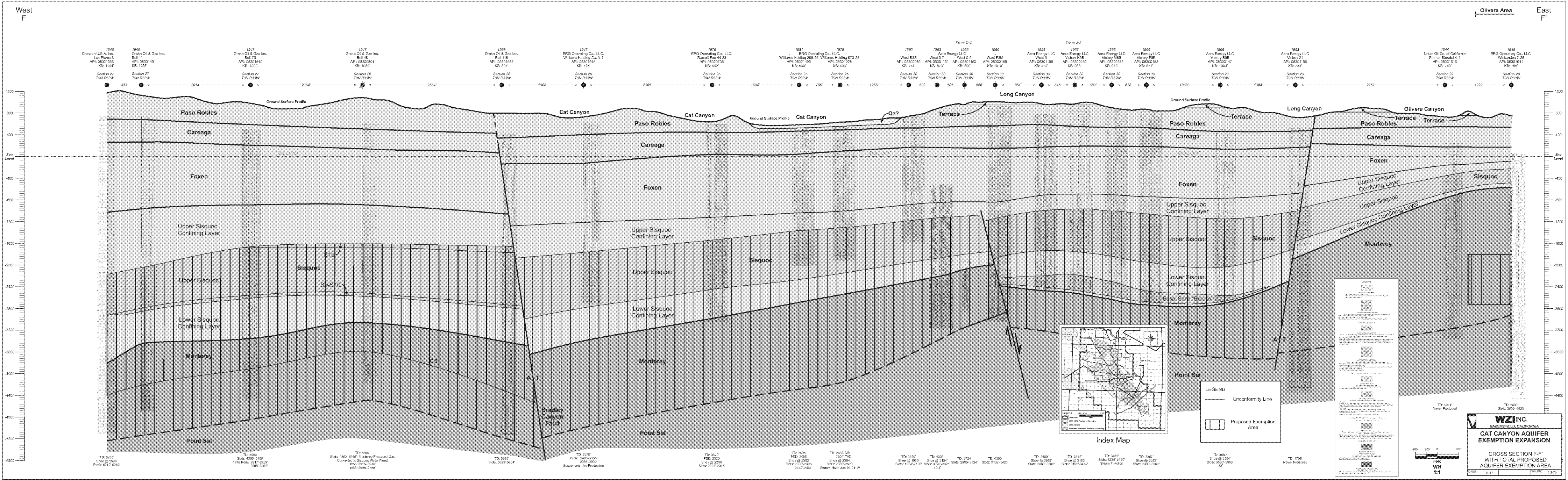


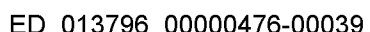


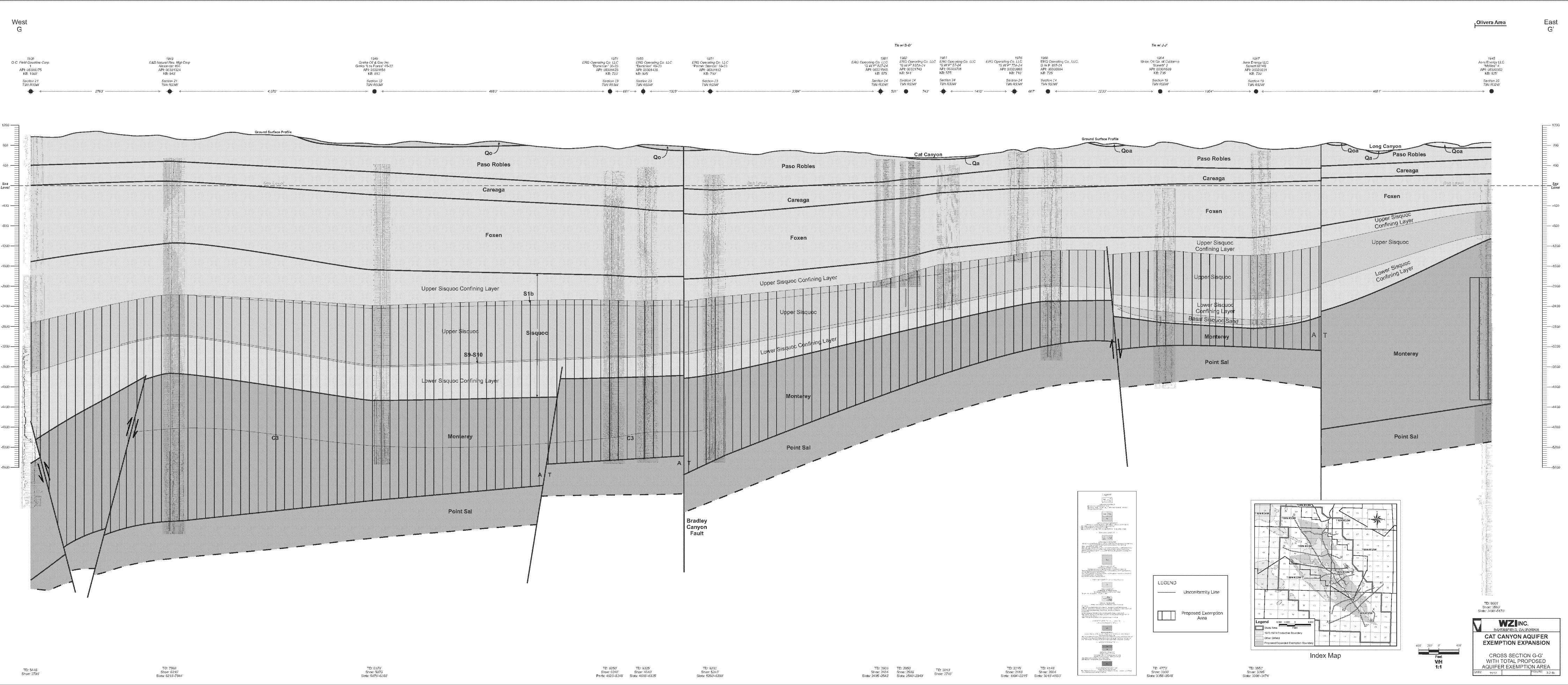




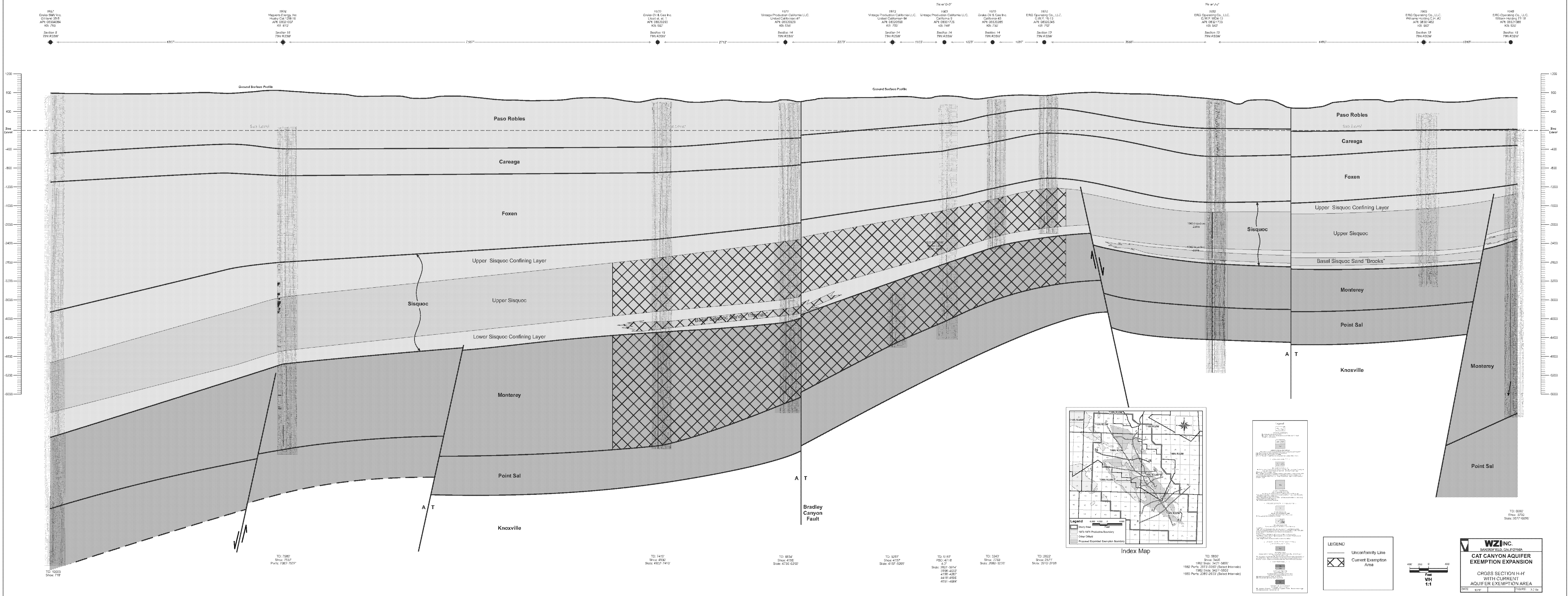




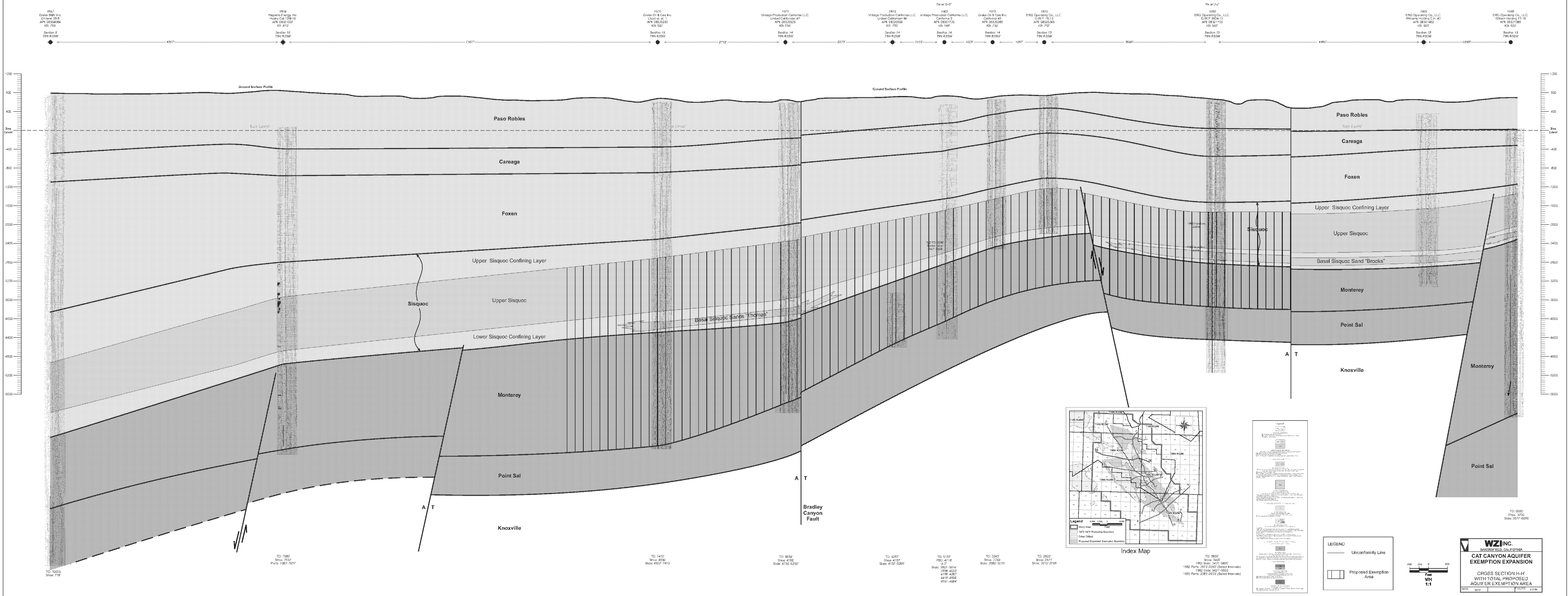




East  
H'



East  
H'



## 4 Regional Geology

### 4.1 General Stratigraphy

The general stratigraphy of the geology is portrayed on **Figure 4.1-1 a, Type Log Gato Ridge Area, Figure 4.1-1b, Type Log Central Areas, Figure 4.1-1c, Type Log West Area, Figure 4.1-1d, Type Log East Area and Figure 4.1-1e, Type Log Sisquoc Area**. Multiple type logs were utilized to avoid misrepresentation of stratigraphy area to area. The surface geology, **Figure 4.1-2 Dibblee Surface Geology Map**, was correlated with the subsurface geology to accurately depict the stratigraphy. The stratigraphy is shown on the cross sections listed below and is discussed in this section:

**Figure 4.1-3 Cross Section A-A';  
Figure 4.1-4 Cross Section B-B';  
Figure 4.1-5 Cross Section C-C';  
Figure 4.1-6a Cross Section D-D';  
Figure 4.1-6b Cross Section D'-D'';  
Figure 4.1-7 Cross Section E-E';  
Figure 4.1-8 Cross Section F-F';  
Figure 4.1-9 Cross Section G-G';  
Figure 4.1-10 Cross Section H-H';  
Figure 4.1-11 Cross Section I-I'; and  
Figure 4.1-12 Cross Section J-J'.**

#### 4.1.1 Alluvium

The surface alluvium is thin to nonexistent over most of the study area, **Figure 4.1-2 Dibblee Surface Geology Map**. Where present (in historic stream channels), the formation consists of interbedded unconsolidates yellowish-brown sands, gravels and clays with pebbles and grains of igneous rock and quartzite, (Bradley & al, 1943). Trending to the north and west of the Cat Canyon Oil Field Aquifer Exemption Expansion Study Area (into the Santa Maria Valley Oil Field) the Alluvium progressively thickens and provides important storage capacity for groundwater. (Worts & Thomasson, 1951), (Bradley & al, 1943).

#### 4.1.2 Paso Robles Formation

The Paso Robles Formation is of Pleistocene age and consists of interbedded conglomerates, sands and clays of continental origin. There are thin fresh-water limestone beds at the base of the clays. The conglomerate of the Paso Robles is composed of black siliceous shale pebbles as well as Monterey shale and chert fragments. On the top of the Gato Ridge, the Paso Robles is not present. Trending to the south and west of the study area the formation reaches a thickness of 2000 feet beneath the central part of the San Antonio Creek Valley, (California Department of Water Resources Board, 2004). The Paso Robles Formation is the main water bearing formation in the San Antonio Creek Valley, (California Department of Water Resources Board, 2004).

#### 4.1.3 Careaga Formation

The shallow marine Careaga Formation, of Pliocene age, unconformably underlies the Paso Robles Formation and is composed of an upper and a lower member. The upper member is a conglomerate composed of black igneous pebbles and ranges in thickness from 50 to 350 feet in thickness. The lower member of the Careaga Formation is separated from the upper member by a thin calcareous sandstone and can be 350 feet thick of loose yellow fine grained sand. Trending from the center of the study area into the adjacent valleys, the Careaga thickens. The Careaga outcrops in the southern portion of the study area and is absent on the southern portion of Gato Ridge (Worts & Thomasson, 1951), (Bradley & al, 1943). To the north of the study area (Northeast corner of Section 35, T10N, R33W) there is a small Careaga outcrop on Fugler Point with tar saturated sands, (Worts & Thomasson, 1951). The outcrop of the Careaga as reported by Worts contains tar, possibly migrating from the steeply dipping underlying Monterey. No tar or oil shows were reported in any of the water wells or exploration core holes which were drilled near the Careaga outcrop.

#### 4.1.4 Foxen Formation

The Foxen Formation, while it has not been mapped on the surface, is a dark gray claystone marine deposit of Pliocene age. In some areas it has minor interbedded sandstones. The Foxen is primarily claystone and appears only in the subsurface. The thickness across the study area ranges from 200 feet to the north and east to up to 2,800 feet to the west and northwest, (Worts & Thomasson, 1951). It is absent on the southern portion of Gato Ridge, thickening to the north and south. The porosity of the Foxen Formation (based on core data) varies from 27% to 46% with permeability ranging from 5 to 0.8 millidarcy, ( $4.8 \times 10^{-6}$  to  $0.6 \times 10^{-6}$  cm/s), having an average permeability of 1.8 millidarcy, ( $1.5 \times 10^{-6}$  cm/s) in the silts and clays that provide the confinement. The core data is contained in **Appendix 4-1, Core Data and Well Histories** along with the tabulated values by well and zone. The Foxen claystone provides the upper confining element to the underlying Sisquoc Formation below the Upper Confining Layer across the entire proposed Aquifer Exemption Expansion Area.<sup>7</sup>

#### 4.1.5 Sisquoc Formation

The lower Pliocene/Miocene marine Sisquoc Formation unconformably underlies the Foxen and is one of the prominent producing formations in the Cat Canyon Oil Field. The Sisquoc consists of an upper zone of siltstone and diatomaceous claystone underlain by thick fine- to coarse-grained sandstone and clay interbeds. These portions of these sandstone beds are productive over the majority of the field. The uppermost sandstone bed is identified as S1b and it pinches out to the north, south and west. The lower portion of the Sisquoc, similar to the Upper Sisquoc, consists of diatomaceous claystone, silty claystone and sandy siltstone. A basal sand which is oil productive is present to the east and west of Gato Ridge structures within the field and are identified by the following names in the subsurface: Brooks (East Area), Santa Margarita (Gato Ridge Area) and Thomas (Sisquoc Area). These sands, although deposited in the same horizon, are not stratigraphically connected as shown on Cross Section D-D' and H-H' (Figure 4.1-6a and 4.1-10, respectively). This basal sand is contained within the Lower Sisquoc claystone with an underlying claystone present above the Sisquoc/Monterey unconformity. The claystone above

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<sup>7</sup> The upper portion of the Sisquoc Formation is primarily low permeability clays and also provides an aerial extensive upper confining layer.

and below the basal Sisquoc Formation below the Upper Confining Layer provides the vertical confinement of the production intervals of the basal Sisquoc Formation below the Upper Confining Layer and the Monterey Formation below. The Sisquoc ranges from 1800 to 2500 feet thick and outcrops where the Howard Canyon crosses Gato Ridge, **Figure 4.1-2, Dibblee Surface Geologic Map**. As shown on Cross Sections A-A', B-B' and D'-D'' (Figures 4.1-3, 4.1-4 and 4.6b, respectively) the Upper Sisquoc Formation below the Upper Confining Layer do not outcrop and are overlain by the Upper Sisquoc claystone. The porosity of the Sisquoc claystone that comprises the Upper Sisquoc Confining Layer based on core data is varies from 27% to 42% with permeability ranging from less than 1 to 95 millidarcy, ( $8.4 \times 10^{-7}$  to  $8 \times 10^{-5}$  cm/s), having an average permeability of 15 millidarcy, ( $1.26 \times 10^{-5}$  cm/s) in the silts and clays that provide the confinement. The Lower Sisquoc confining clay has permeability with a range from 100 to 0.03 millidarcy, ( $8.4 \times 10^{-5}$  to  $2.5 \times 10^{-8}$  cm/s) with the average being 11 millidarcy, ( $9.2 \times 10^{-6}$  cm/s). The core data is contained in **Appendix 4-I, Core Data and Well Histories** along with the tabulated values by well and zone.

#### 4.1.6 Monterey Formation

The Monterey Formation of upper Miocene age in the Gato Ridge Area of the Cat Canyon Oil Field was identified as one of the most important naturally fractured reservoirs in the United States, (Hubbert & Willis, 1955). The Monterey is a deep water marine deposit, consists of three distinct lithologic members: an upper platy siliceous shale member, a middle fractured chert/dolomitic member and the lower limy shale member, (the Buff and Tan). In the Gato Ridge Area all three members were completed with about 60% of the production coming from the chert member. In the West Area, the cherty zone is the primary completion interval. The Monterey Formation thickness ranges from zero, where it pinches out on the basement complex to the east of Gato Ridge, to over 2,500 feet over most of the study area. A maximum thickness of approximately 4,000 feet occurs in the Olivera Area. The Monterey chert zone has an estimated permeability of  $10^{-15}$  darcy ( $8.4 \times 10^{-3}$  to  $1.26 \times 10^{-2}$  cm/s) with a maximum of 35 darcy ( $2.94 \times 10^{-2}$  cm/s) but an effective porosity of 6%, (Hubbert & Willis, 1955).<sup>8</sup> In the Cat Canyon Oil Field and surrounding oil fields, the Monterey Formation is both the source rock as well as the producing reservoir rock. While core data has been taken in the Monterey, it is not considered representative of the total formation properties due to the localized natural fracturing, (Nelson, 2001). The data is included in **Appendix 4-I, Core Data and Well Histories, Core Data Summary Table**, for completeness.

#### 4.1.7 Point Sal Formation

The Point Sal Formation is marine deposit of middle Miocene age which conformably underlies the Monterey Formation. It consists of siltstone and diatomaceous siltstone with fine-grained sandstone and lenses of sandstone and conglomerate. The average thickness is 750 feet which provides the lower vertical confinement for the Monterey Formation. **Figure 4.1-1, Type Logs**, shows the Point Sal in its relationship to the Monterey. The permeability of the Point Sal is estimated as less than 1 millidarcy ( $8.4 \times 10^{-7}$  cm/s), (Freeze & Cherry, 1979).

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<sup>8</sup> The high permeability accounts for the Monterey's ability to produce large volumes of heavy oil.

### 5.1.3 Proposed Exemption Formation Water Quality

#### 5.1.3.1 Summary of all Cat Canyon Areas and Formations

All available formation water samples were reviewed for veracity and accuracy in terms of representing the conditions of water that would be found in the subject formations, **Appendix 5-IV, Formation Water Analysis and Data. Table 5.1-4, Summary of Reviewed Data by Area and Formation** show the results by Area and formation. The Sisquoc Area Monterey data was not available therefore the East Area Monterey data (mean [TDS] = 10,417 mg/L) were used as a close analog.

Area	Formation		TDS	B	Na	CL	SO4	HCO3	Ca	K	Mg
Sisquoc	All Sisquoc Data		10281	26	1143	3142	116	4530	118	49	207
		Std. Dev.	8352	9	709	2839	211	4962	54	57	172
		Count	33	24	29	31	29	31	10	29	29
	Sisquoc: Post Steaming Production	Mean	5707	25	961	1756	75	2209	104	41	247
		Std. Dev.	2422	9	426	980	46	1572	50	60	179
		Count	22	20	22	22	22	22	8	22	21
	Sisquoc: Native Sisquoc Formation	Mean	19862	34	2311	7436	295	11004	113	71	91
		Std. Dev.	7558	17	1612	2269	500	6143	67	46	113
		Count	12	4	7	10	5	8	2	6	7
	Monterey	Mean	10417	7	1153	3216	57	4657	82	26	98
		Std. Dev.	6445	5	798	1828	51	2395	73	23	82
		Count	14	14	14	14	14	14	6	14	12
Central	Sisquoc	Mean	10745	28	1641	4001	47	5539	29	36	21
		Std. Dev.	3815	20	801	1420	22	2496	8	24	17
		Count	14	11	11	11	11	11	4	11	8
	Monterey	Mean	12314	19	1188	4033	67	5109	44	41	56
		Std. Dev.	6823	22	454	1958	87	2221	7	68	37
		Count	17	7	16	16	17	17	5	16	15
East	Monterey	Mean	10417	7	1153	3216	57	4657	82	26	98
		Std. Dev.	6445	5	798	1828	51	2395	73	23	82
		Count	14	14	14	14	14	14	6	14	12
	Sisquoc	Mean	7668	12	1263	2740	27	3528	41	16	75
		Std. Dev.	2547	12	768	1019	20	1806	12	11	51
		Count	17	9	14	14	14	14	2	13	13
West	Monterey	Mean	12314	19	1188	4033	67	5109	44	41	56
		Std. Dev.	6823	22	454	1958	87	2221	7	68	37
		Count	17	7	16	16	17	17	5	16	15
	Sisquoc	Mean	22007	42	876	8063	147	12252	15	50	49
		Std. Dev.	5280	29	442	2096	103	3700		28	94
		Count	9	5	8	8	8	8	1	8	5
Gato Ridge	Monterey	Mean	9118	29	1769	3207	29	4003	41	14	62
		Std. Dev.	1151	14	528	367	11	698	11	10	74
		Count	55	40	42	51	52	42	5	40	34
	Sisquoc	Mean	21000								
		Std. Dev.									
		Count	1								
	Sisquoc/ Monterey	Mean	6333								
		Std. Dev.	153								
		Count	3								

#### 5.1.3.2 Sisquoc Formation Water Quality

Consistent formation water samples from the Sisquoc Formation are difficult to obtain in the higher oil saturation areas where the Sisquoc is most productive. The difficulty in obtaining formation water samples is due to the physical phenomena known as relative permeability as illustrated in a technical research study by Statoil, (Nejad, Berg, & Ringen, 2011). The oil contained in the Sisquoc in Cat Canyon varies from a high of 12.5° API to a low of 8.5°API both of which are crude oils with very high viscosities in the hundreds of thousands centipoises. In addition based on the core data gathered in the normal course of business, the oil saturations in the more permeable portions of the Sisquoc are unusually high for an oil and gas producing

formation in California often exceeding 70% of the total fluid saturations. The result is that there is little if any permeability, or ability to flow, for the native formation waters. The figure below illustrates the Sisquoc relative permeability to both oil and water.

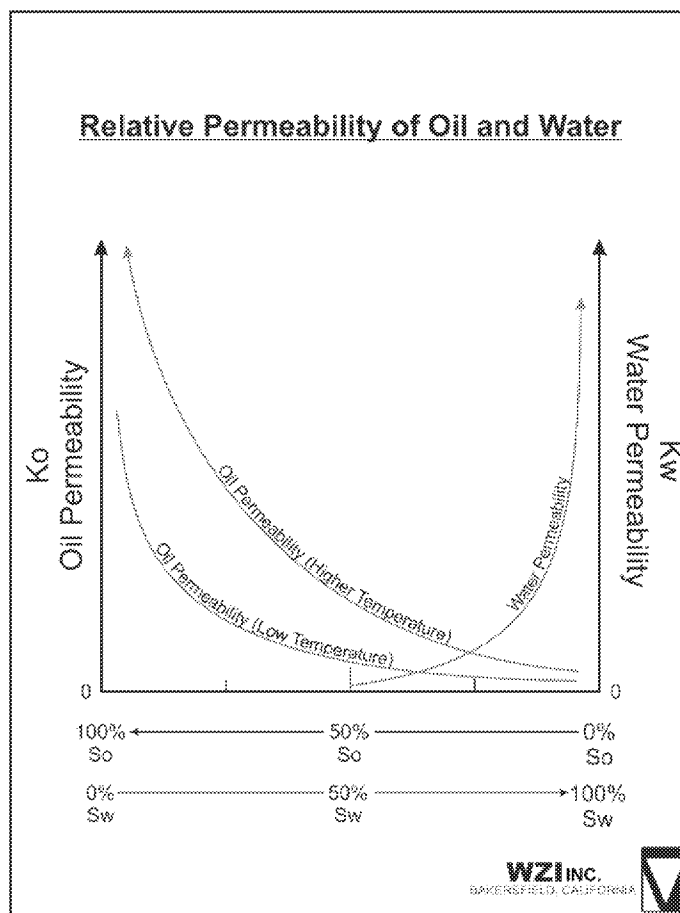


Figure 5.1-16

Initial production without the assistance of steam illustrates the point. At the initial saturation, the Sisquoc has low oil production with no measurable water.

With the addition of steam the viscosity of the oil is reduced and the near well bore saturation of water is increased allowing some of the water utilized in the cyclic steam to be produced back to the well. However, the near well bore radius is re-saturated with oil once again as the production takes place reducing the relative permeability to water to a low value. As the re-saturation process proceeds the near well bore radius relative permeability effect captures not only the formation water but also a portion of the water utilized in the steaming process. The water thus produced and sampled does not represent the native formation water chemical constituents but a combination of the water that is injected as steam including dissolved formation constituents, and some component of the formation water. As the cyclic process continues in an individual area and the depletion of the oil increases, the near well bore area increases in water saturation, however, the concentration of the adsorbed steam condensate also increases further confounding the ability for a reliable formation water sample to be collected.

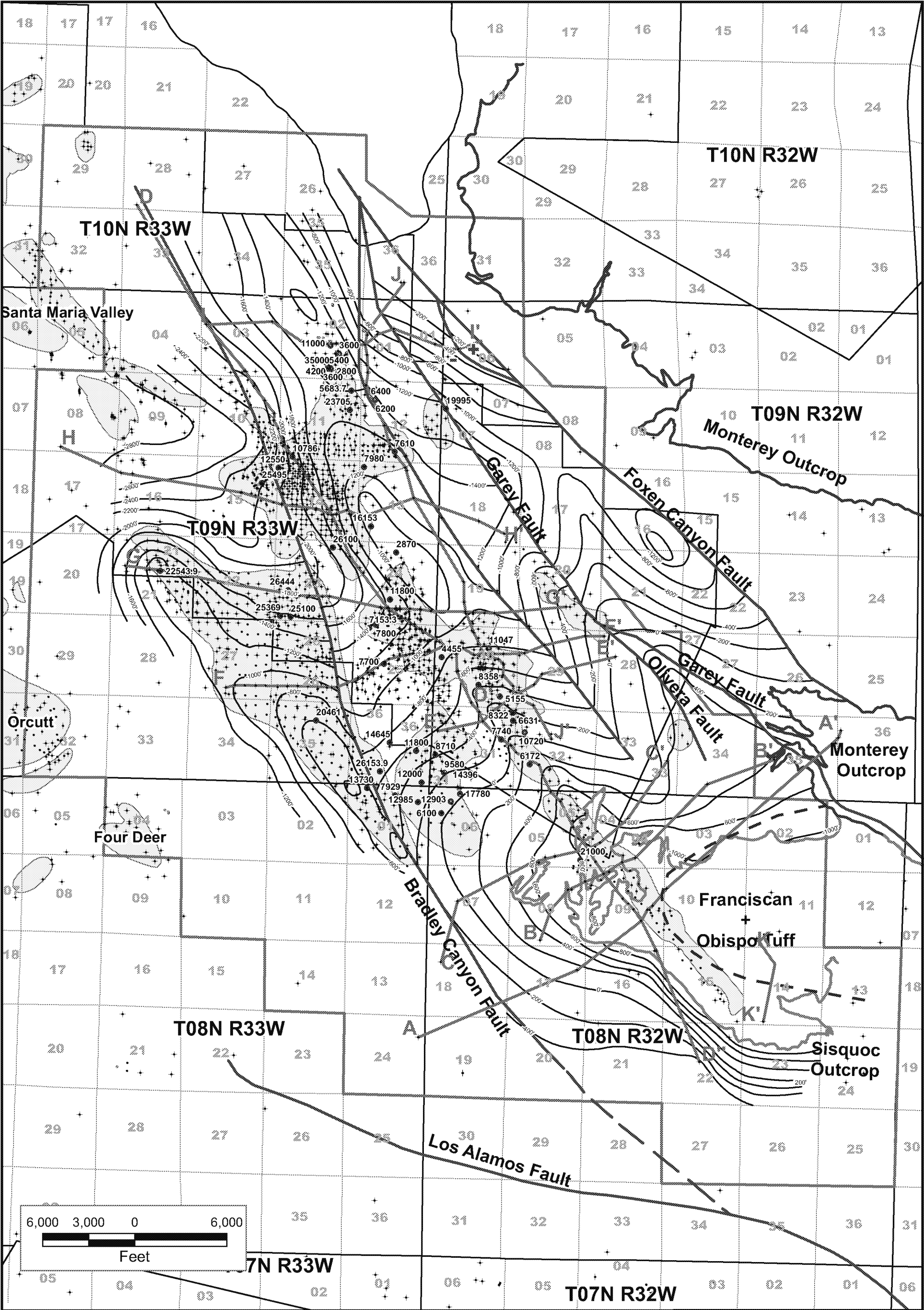
In areas where the oil saturation in the Siquoc is lower than 45%, there is a higher likelihood of formation water sample collection. In these areas such as the West Area, the samples collected without the introduction of steam are considered to be formation water samples. The Siquoc Formation below the Upper Confining Layer water quality (for the purpose of the proposed Aquifer Exemption Expansion in the Siquoc Formation below the Upper Confining Layer) is considered to be variable within each Area of Cat Canyon Oil Field based on past production practices and quantities of steam condensate returned as production fluid. The individual areas and ranges of water quality are discussed briefly in the following section and in more detail in the **Appendix II, Formation Water Quality Study** of the proposed Aquifer Exemption Expansion Study **Appendix 6-1, Water Treatability Study**.

**Table 5.1-5, Summary of Siquoc Formation below the Upper Confining Layer Water Reviewed Data by Area** below lists the water quality in TDS based on statistical analysis by Production Area. The table indicates the maximum deviation as well as the mean. Although the connate Siquoc Formation below the Upper Confining Layer water TDS is most likely more than 10,000 mg/L, the samples that are able to be collected which include the steam condensate and the reinjected produced water, (which also includes the steam condensate), at the low end of the range may be less than 10,000 mg/L thus requiring an exemption expansion proposal.

Table 5.1-5: Summary of Siquoc Formation below the Upper Confining Layer Water Reviewed Data by Area, (mg/L)											
Area			TDS	B	Na	CL	SO4	HCO3	Ca	K	Mg
Siquoc	All Siquoc Data	Mean	10281	26	1143	3142	116	4530	118	49	207
		Std. Dev	8352	9	709	2839	211	4962	54	57	172
		Count	33	24	29	31	29	31	10	29	29
	Siquoc: Post Steaming Production	Mean	5707	25	961	1756	75	2209	104	41	247
		Std. Dev	2422	9	426	980	46	1572	50	60	179
		Count	22	20	22	22	22	22	8	22	21
	Siquoc: Native Siquoc Formation	Mean	19862	34	2311	7436	295	11004	113	71	91
		Std. Dev	7558	17	1612	2269	500	6143	67	46	113
		Count	12	4	7	10	5	8	2	6	7
Other Areas	Central Area	Mean	10745	28	1641	4001	47	5539	29	36	21
		Std. Dev	3815	20	801	1420	22	2496	8	24	17
		Count	14	11	11	11	11	11	4	11	8
	East Area	Mean	7668	12	1263	2740	27	3528	41	16	75
		Std. Dev	2547	12	768	1019	20	1806	12	11	51
		Count	17	9	14	14	14	14	2	13	13
	West Area	Mean	22007	42	876	8063	147	12252	15	50	49
		Std. Dev	5280	29	442	2096	103	3700		28	94
		Count	9	5	8	8	8	8	1	8	5
	Gato Ridge Area	Mean	21000								
		Std. Dev									
		Count	1	0	0	0	0	0	0	0	0

In the West Area, as shown in the Table above the Siquoc Formation below the Upper Confining Layer water sample average TDS of 22,007 mg/L with a standard deviation of 5280 mg/L, thus not requiring an exemption expansion proposal. However, due to future steaming potential the Aquifer Exemption Expansion is being sought for the Siquoc Formation below the Upper Confining Layer in the West Area.

The Siquoc Formation below the Upper Confining Layer water quality sampling results are shown in a map view on **Figure 5.1-17, Siquoc Structure Water Quality Map**.



**Legend**

**Well Status**

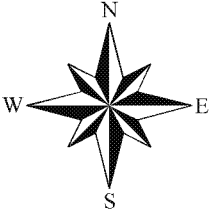
- Active
- + Buried
- + Idle
- New
- + Plugged
- Cross Section

- • Volcanics
- Monterey Outcrop
- Sisquoc Outcrop
- Faults
- Top Sisquoc Structure Contours
- Study Area

- 1973-1974 Productive Boundary
- Other Oilfield

**Fault Throw**

- Down
- Up
- Sisquoc Water Quality Wells, Most Recent Data (TDS: mg/L)



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**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

SISQUOC STRUCTURE  
WATER QUALITY MAP

DATE: 10/17

FIGURE: 5.1-17

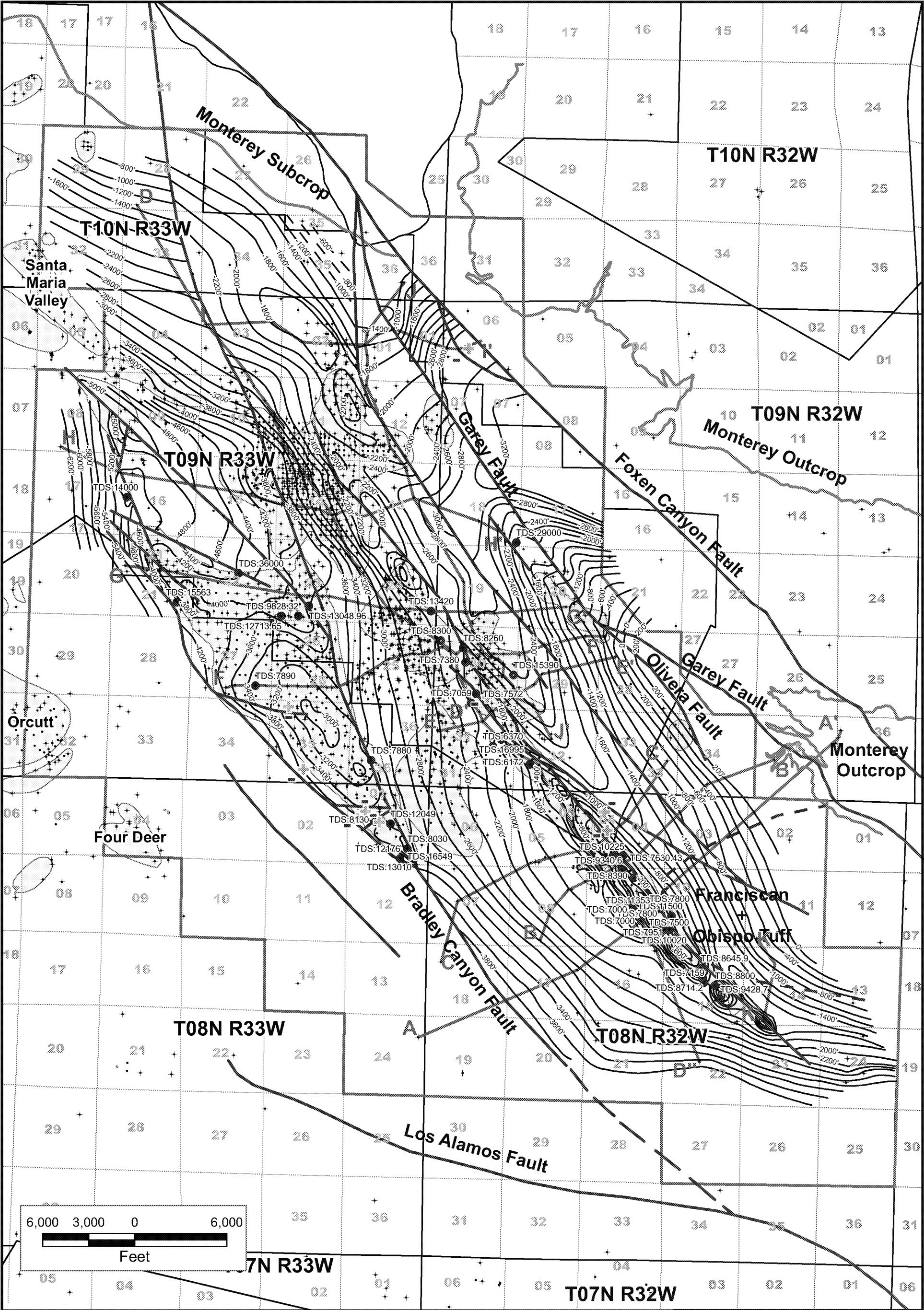
### 5.1.3.3 Monterey Formation Water Quality

The Cat Canyon Oil field is a major producing area for the Monterey Formation. The produced water from the Monterey has been sampled on numerous occasions. The Monterey is subject to reinjection of produced water and occasionally produced natural gas for Waterflood and production at Maximum Efficient Rate, (MER). The samples are not confounded by steaming.

**Table 5.1-6, Summary of Monterey Formation Water Reviewed Data by Area** below lists the water Quality in TDS based on statistical analysis by production Area. The table indicates the maximum deviation as well as the mean.

Table 5.1-6: Summary of Reviewed Data by Area and Formation(mg/L)											
Area	Formation		TDS	B	Na	CL	SO4	HCO3	Ca	K	Mg
	Sisquoc Area	Mean	10417	7	1153	3216	57	4657	82	26	98
		Std. Dev.	6445	5	798	1828	51	2395	73	23	82
		Count	14	14	14	14	14	14	6	14	12
	Central Area	Mean	12314	19	1188	4033	67	5109	44	41	56
		Std. Dev.	6823	22	454	1958	87	2221	7	68	37
		Count	17	7	16	16	17	17	5	16	15
	East Area	Mean	10417	7	1153	3216	57	4657	82	26	98
		Std. Dev.	6445	5	798	1828	51	2395	73	23	82
		Count	14	14	14	14	14	14	6	14	12
	West Area	Mean	12314	19	1188	4033	67	5109	44	41	56
		Std. Dev.	6823	22	454	1958	87	2221	7	68	37
		Count	17	7	16	16	17	17	5	16	15
	Gato Ridge Monterey Only	Mean	9118	29	1769	3207	29	4003	41	14	62
		Std. Dev.	1151	14	528	367	11	698	11	10	74
		Count	55	40	42	51	52	42	5	40	34
	Gato Ridge Sisquoc/ Monterey	Mean	6333								
		Std. Dev.	153								
		Count	3								

The Monterey Formation water quality in TDS is shown on **Figure 5.1-18, Monterey Formation Water Quality Map**. As noted on the map, the north western area of the Cat Canyon Oil Field as it deeps steeply into the Clark Area of the Santa Maria Oil Field contains formation waters that are significantly above 10,000 mg/L. The remainder of the Cat Canyon Oil Field is documented to have a water quality while greater than 3000 mg/L is less than 10,000 mg/L.



**Legend**

**Well Status**

- Active
- Buried
- Idle
- New
- Plugged

**Faults**

- Monterey Pinchout
- Volcanics
- Approx. Top Monterey Structure
- Top Monterey Structure
- Monterey Outcrop
- Cross Section
- Study Area

**Fault Throw**

- Down
- Up
- Monterey Water Quality Wells, Most Recent Data (TDS: mg/L)
- 1973-1974 Productive Boundary
- Other Oilfield

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BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

MONTEREY STRUCTURE  
WATER QUALITY MAP

DATE: 10/17

FIGURE: 5.1-18

#### 5.1.4 Proposed Aquifer Exemption Ground Water Gradient

The direction of groundwater flow in the Sissuoc Formation below the Upper Confining Layer, and Monterey Formation in the various producing areas of Cat Canyon Oil Field is toward the producing wells and is controlled by the production processes due to the withdrawal of fluids, both oil, water and gas as well as the introduction of water used for steam and subsequent reinjection of produced water and gas in achieving Maximum Efficient Rates of Production (MER), **Figure 5.1-19, Sissuoc Formation Gradient Map with Pressures** and **Figure 5.1-20, Monterey Formation Gradient Map with Pressures**. The maps were constructed based on static fluid level data collected as a portion of this study. The fluid levels were converted to pressures and the pressures were then plotted to indicate the direction of flow. The pressure data also documents the sealing nature of the faults in the Cat Canyon Oil Field. In addition to the pressure gradient evidence, the direction of flow is documented by the Material Balance calculations for the year 2016. The direction of flow and the gradients are dependent on the volumes of production and injection. Since the material balance demonstrates a significant decrease in fluid content in the reservoirs, the inward gradient and decrease of pressure in the productive areas will remain in effect for the life of the field and thereafter until pressure equalization is completed. Once the pressure has been equalized flow will cease.

**Table 5.1-7, Cumulative Material Balance Field Wide Summary – Cat Canyon** shows the Cat Canyon Oil Field cumulative production and injection for the period up to 1977 (the start of DOGGR records) and up to 2016 (the last complete record year as of this study). The water injection into the Cat Canyon Oil Field is from the formations in the Cat Canyon Oil Field. No water is imported to the Cat Canyon Oil Field from any other oil field. Historically, most produced water was not reinjected but rather was sent out of the Study Area to the Santa Maria River, Pacific Ocean, or piped to the Battles Gas Plant where it was treated and then put into the outfall. **Appendix 5-V, Fluid Levels and Material Balance** contains a map showing the historic gathering system. Starting in 1947 water was reintroduced for disposal and in 1963 water was reintroduced for cyclic steaming purposes and starting in 1954 water was reintroduced for flooding. Since then the practice of reinjection of in-field produced water has increased to promote Enhanced Oil Recovery.

Presently, the water is injected as steam, water flood and produced water reinjection. The quality of the reinjected water is dependent on the steaming operations due to the relative permeability of the oil and water. The reinjected water has a major component of steam condensate. Once-through boilers are tolerant of high dissolved solids (up to 7,000 mg/L). They are designed to deliver low-quality steam (steam that is not 100% vapor) but these boilers are still limited by scaling, oxygen and sulfates thus requiring treatment and mixing, lowering the TDS of the reinjected (low quality) steam relative to the native formations, (Henry L. Dogherty Series, 1986). The returned condensate (scheduled for reuse after treatment) may contain some formation water from the capture radius depending on the specific formation conditions.

Table 5.1-7: Cumulative Material Balance Field Wide – Cat Canyon						
Cumulative to:	Production		Injection			Balance
	Oil	Produced Water	WF	SF/SC	WD	
<b>1977</b>	228,852,985	898,501,621	176,028,000	33,360,333	63,722,653	(805,407,026)
<b>2016</b>	310,496,930	1,416,140,580	880,702,927			(845,934,583)

Individual operators have provided information where possible delineating the inter-formation mass balance by the area and/or by their lease, **Appendix 5-V, Fluid Levels and Material Balance**. The long term net negative balance for the Study Area is supported by the injection and production data as well as the pressure gradients of the formations. A copy of the calculations and data are included in **Appendix 5-V, Fluid Level Data and Material Balance**.